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**APPLIED SCIENCE DIVISION**

LITTON SYSTEMS, INC.

LITTON INDUSTRIES

26 September 1966

FINAL REPORT

Suntracker Balloon Flights

Flights 3033, 3034, 3035 and 3037

JPL CONTRACT 951539

"This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, pursuant to a subcontract, issued under Prime Contract NAS 7-100 between the California Institute of Technology and the United States of America represented by the National Aeronautics and Space Administration".

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Report No.: 3034
Project No.: 59615

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# FINAL REPORT

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## I. INTRODUCTION

### A. General

Flights 3033, 3034, 3035 and 3037 were a planned series of four balloon flights conducted during July and August 1966, for Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under subcontract 951539 to JPL. This contract provides for all necessary balloon flight services, including those required for flight preparation, functional verification of the flights and data acquisition systems, tracking of the balloon aloft by aircraft, and the recovery and return of equipment after its descent to the surface. Meteorological services were included in this contract. Balloons, helium, power supplies, antennas and other equipment required for the flights were supplied separately under purchase order BQ-384813.

### B. Flight Objectives

1. Launch and ascend to an altitude of 80,000 feet ±4000 ft, three balloon systems with suntracker, solar cells, and instrumentation mounted atop the balloon; with telemetry and other instrumentation, and power supply mounted below the balloon. Launch a similar system to achieve an altitude of 120,000 ±6000 ft.

2. Telemeter altitude and solar cell data during ascent and during a floating period of four hours, minimum. The floating period shall commence before 11:00 CDT and shall be maintained until 15:00.

3. Descend to surface level with balloon and payload intact.

4. Deflate balloon automatically upon impact by firing an explosive cord which opens the side of the helium filled balloon bubble for the purpose of recovering the top-mounted suntracker and solar cells with minimum damage.

5. Recover and return all equipment, except the balloon, to Litton.

All major objectives of this program were accomplished. The four flights attempted this year were successful in that each balloon reached its expected altitude, the suntrackers and telemetry system operated continuously throughout each flight and all equipment and solar cells were recovered without major problems. This is the second consecutive yearly program for Jet Propulsion Laboratories that achieved 100% balloon success (4 flights out of 4 attempts). The state-of-the-art, as far as high precision solar cell calibration is concerned, was advanced when the final flight attained a float level of 120,000 ft permitting, for the first time, a direct comparison of solar cell outputs obtained previously to data obtained at this higher altitude.

## II. FLIGHT 3033

### A. Flight Preparations

#### 1. Project Personnel Assignments

Litton personnel responsible for preparations and flight operations on Flight 3033 were as follows:

| | |
|---|---|
| Upper Air Programs Manager: | R. Wood |
| Project Engineer: | R. Conlon |
| Flight Leader: | C. Wise |
| Instrumentation: | E. Minnich<br>L. Nelson |
| Launch | M. Lueders |
| Recovery | J. Chesebro<br>D. Harshman |

#### 2. Pre-Flight Checkout

Required repairs and preventive maintenance were performed on all ground-station electronic support equipment. Other than the routine replacement of weak tubes, the only repair required was the trouble-shooting and subsequent replacement of a time-delay relay. This relay in the primary telemetry receiver had failed on the final flight of the previous program. To improve ground-station reliability, an air-conditioned telemetry van was outfitted to house the equipment previously installed in a telemetry bus.

A solid-state voltage regulator was designed for the purpose of eliminating suntracker instability due to battery voltage decay. Tracker #2 was tested to determine its current vs. voltage characteristics for all drive positions and the resulting current requirements used for the regulator design. The series regulator circuit consists of two NPN silicon transistors in a Darlington configuration. The base of the drive transistor is controlled with a 22-v Zener regulator diode. A bias resistor, noise filter capacitor, and output decoupling capacitor complete the circuit. A schematic of the regulator is shown in Fig. 1. Components were obtained for two regulators. One unit was built, installed on the chassis of tracker #2, bench checked, environmentally checked, and then tested with the unit in the sun. The unit operated properly and was stable over a supply voltage range of 22 to 32 v.

Inquiries were made to a number of manufacturers of stepping switches suitable for use as a replacement for the 24-position Oak solenoid stepper used in electronic box #1. Some companies offered units with improved characteristics and many have equivalent units, but delivery schedules ranged from two to six months which was unacceptable for use on this project. Oak, on the other hand, offered to ship a replacement switch in time for the first flight. The unit did not, however, arrive on schedule so the original stepper was flown on this flight.

The on-board voltage reference output circuit was revised from 20 mv to 100 mv, full scale output, and adjusted for the desired voltage ratios. A Leeds and Northrup model K3 voltage potentiometer and a newly calibrated Eppley standard cell were used for final calibration. The standard cell was checked and updated using a voltage source directly traceable to the National Bureau of Standards. Final calibration of the reference system placed the full-scale reference voltage within 6 μv of the desired 100-mv setting. Largest percentage error occurred at the 25-mv setting, where the actual reading was 0. 12% below the nominal value. A chart containing actual voltages and frequencies obtained in final calibration is given in Appendix page A-5. Primary temperature channels were calibrated using a resistance decade to simulate temperature levels of 0, 20 and 40 C. Secondary temperature circuitry was checked; the commutator

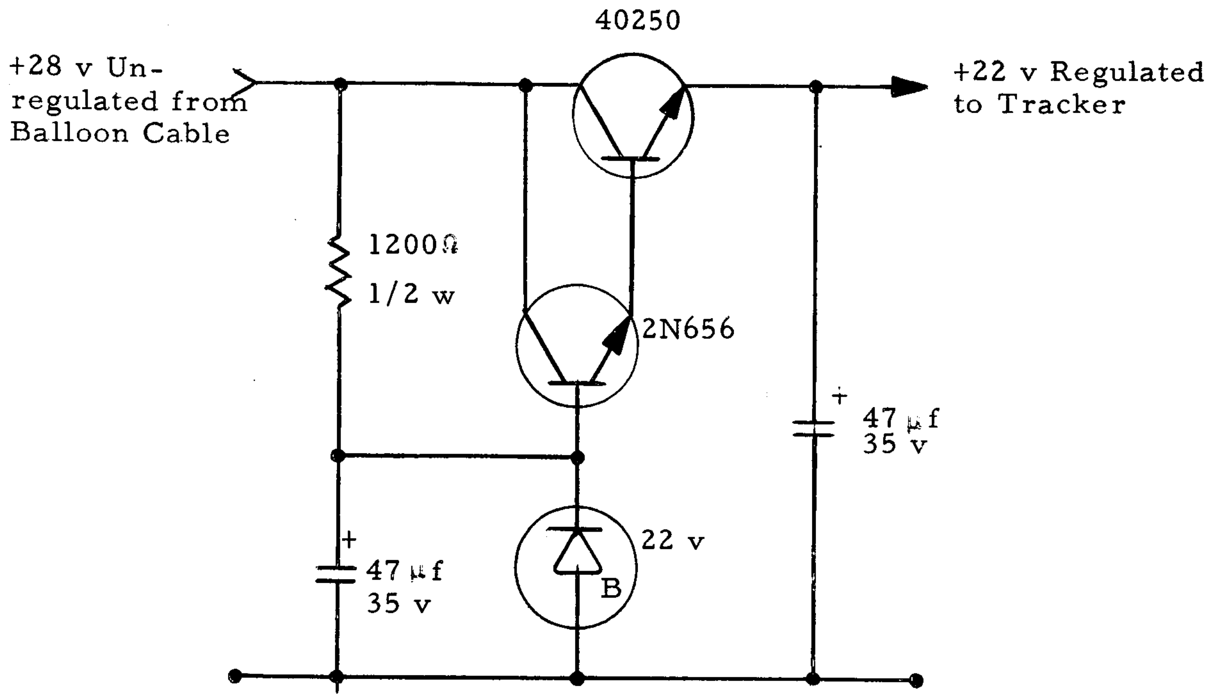


Fig. 1. Schematic of Suntracker Voltage Regulator

was cleaned, and the output frequencies monitored and found nominal. Modulation voltage levels from the data subcarrier, temperature subcarriers, and on-sun sensor were checked and found nominal.

As a final system check, the entire top-mounted payload was attached to the tracker-mounting disc and the balloon top end fitting. Actual balloon and parachute cables were connected and the system put in operation while in the sun. System performance was perfect with no sign of noise or instability.

## B. Field Operation

### 1. Launch

Preparation began at 0600 CDT on 29 July 1966, with the auxiliary battery attachment, heater and regulator turn-on, and the warm-up of the telemetry van gear. Wind velocity was NNE at 2 mph at the start of the balloon layout and increased to 5 mph by launch time. Launch preparation and instrumentation checkout proceeded without incident through the inflation period. A discrepancy in the secondary temperature telemetry system now atop the balloon was found, but this did not delay launch significantly. The system was successfully launched at 08:58 using the bubble downwind dynamic launch technique with the lower payload mounted on the front of the launch vehicle.

### 2. Tracking and Recovery

Flight 3033 ascended on a southeasterly course to a point over Martell, Wisconsin, at 10:36 CDT, the beginning of the float period. During float, the system moved west-southwest until reaching a point near Cleveland, Minnesota at the initiation of descent. The deflating balloon moved southeast during system descent to an impact point 2 miles SW of Geneva, Minnesota. The tracking aircraft observed the touch-down in an



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open pasture and could see that the impact switches did not immediately actuate the balloon destruct device. Ground winds were nearly calm and the system remained upright for several moments until the lower payload moved a few feet and the destruct was actuated. The lack of wind may actually have resulted in greater tracker damage than normal because the top-mounted equipment was dropped abruptly to the ground as the bubble deflated. After guiding the recovery truck to the location, the aircraft landed on the roadbed on Interstate Highway 35 under construction at the edge of the pasture. The crew assisted the recovery personnel and all returned to Minneapolis that evening.

### C. Flight Results

#### 1. Balloon

The balloon used on this flight was similar in diameter and carried the same model number as those used on this program in previous years. However, the length and volume were increased slightly, compared to the previous design, in order to achieve a slightly higher altitude; see the revised operational specification sheet included as Appendix page A-1 to this report. The flight system configuration was identical to last year's (see Fig. 2).

Using 8% free lift, the average rate of rise was 797 fmp (feet per minute) to an average float altitude of 78,500 feet. The altitude remained constant within 1000 feet throughout the float period. The maximum recorded altitude was 79,000 feet. The float period began at 10:36 CDT and the system remained above 76,000 feet for a period of four hours and 42 minutes.

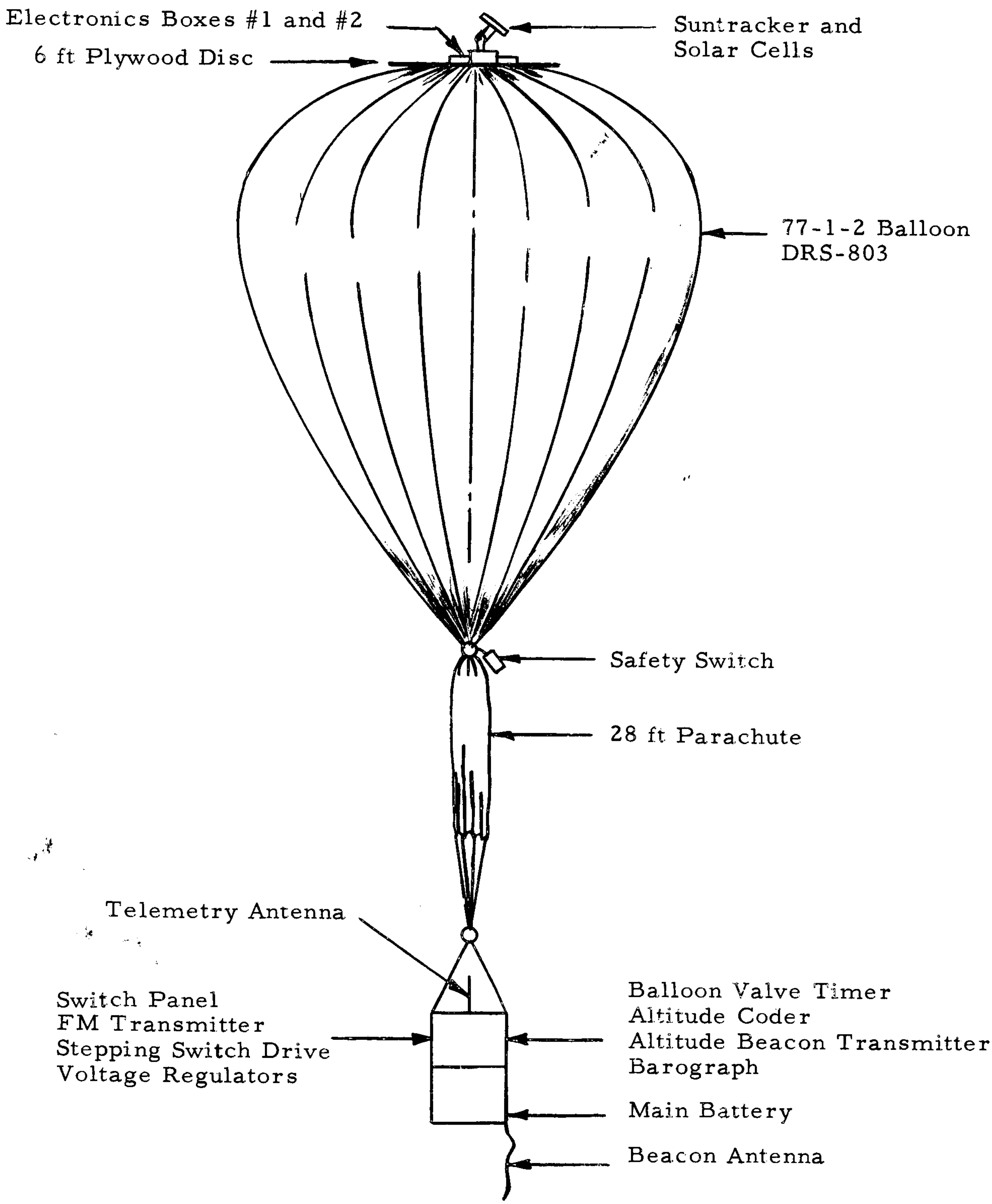


Fig. 2. Balloon Flight Configuration

## 2. Instrumentation

The suntracker, data cycling switch, telemetry transmitter, voltage reference circuitry and other primary components of the system all performed flawlessly throughout the flight. A minor discrepancy was uncovered during inflation. The secondary temperature commutator failed to start cycling after power was switched from auxiliary to primary battery. Consequently, only one secondary temperature, the bottom of the tracker mounting plate temperature, was monitored throughout the flight. It can be concluded that the remaining temperatures were completely normal from the known stability of the telemetered on-board calibration voltages. The secondary temperature data obtained on this flight are found in the Appendix page A-6.

A more annoying discrepancy began during system ascent and continued throughout the float period. The analog recorder revealed that several solar cell output channels exhibited noise or interference. About four channels among the first group of solar cell outputs were affected. The interference could be correlated with keying of the 1.746 MHz beacon transmitter. Keying the transmitter off caused an apparent shift in output on the four affected channels; all other data positions (20) were perfectly stable. The amplitide of the shift was variable but always less than a 2-ma peak variation. The digital recording of the cell outputs was also affected but because the electronic counter averages the instantaneous readings over a one-second period, the amount of error was less than one percent. By careful interpretation of the digital readout the data analyst may be able to eliminate these errors completely.

The suntracker (unit #2, as flown on all flights in 1965) was damaged extensively. Although the cells were not damaged, the mounting plate and main shaft were bent, the on-sun sensor broken and three limit switches smashed.

## III. FLIGHT 3034

### A. Flight Preparations

#### 1. Project Personnel Assignments

(same as Flight 3033)

#### 2. Pre-Flight Checkout

Suntracker #1 (last used on all 1964 flights) was set up, the voltage regulator circuitry installed and the unit checked out by an on-sun test for use on this flight. The on-sun test of the tracker alone was satisfactory, but on a later complete system check the tracker performed irradically and voltage regulation was not maintained. Substitution of the other regulator did not cure the instability. The problem was localized with an oscilloscope revealing a high-frequency oscillation on the power input line following the regulator. A filter capacitor at the regulator output eliminated the problem. During this troubleshooting, a wiring difference was discovered between the two units. Tracker #1 acquisition circuits was re-wired to conform to unit #2's improved circuitry and the system was rechecked in the sun.

Troubleshooting the entire telemetry system failed to reveal a positive cause of the interference found on the previous flight. Since the interference was noticed in conjunction with keying of the beacon transmitter, the effect of keying transients or radio-frequency pickup by the long balloon cable was suspected. A large amplitude inductive transient was in fact found when viewing the keying relay coil voltage with an oscilloscope. The inductive kick was eliminated with a diode installed across the relay coil. Radio frequency transmission on the balloon power cable was diminished by isolating the beacon transmitter by installing RF chokes in the positive and negative power leads at the transmitter's input.

Final calibration of the reference voltages showed them to be essentially the same as when checked before Flight 3033. The maximum variation from the desired voltage level was only 36 $\mu v$ at the 25-mv level. All other calibration points were actually closer to the ideal readings than on the previous flight; see Appendix page A-5. The on-sun circuit modulation levels and secondary temperature circuit were tested and found not to have changed from the previous flight. Although the secondary temperature commutator had failed to start when power was applied during the last flight, it was now operating properly. A recurrence of the stoppage will be prevented by changing the checkout procedure slightly on this and all future flights. Since the battery pack has considerable reserve power, it will be permanently connected to the system before balloon inflation. This will enable us to manually start the commutator, if required, in the future.

B. Field Operation

1. Launch

Launch preparations for Flight 3034 began on schedule on 4 August 1966. Balloon layout began at 07:00 CDT with wind velocity of 6 to 8 miles per hour. Because of the interference in the telemetry system encountered on the last flight, radio-frequency interference (RFI) testing was conducted with the entire system layed out and operating, including the 270-ft long beacon antenna. Various conditions of antenna angle and mismatch were tried but the problem as seen on the previous flight could not be induced. At 08:00, inflation began under wind conditions varying from 6 to 12 mph. Predicted launch conditions were good except that surface winds were expected to be only marginally acceptable. Wind velocities were higher than forecast with gusts actually reaching 15 mph. The balloon bubble was buffeted considerably but suffered no apparent damage. Inflation and final checkout were



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conducted as rapidly as possible to minimize wind-caused stress on the bubble. Launch was accomplished at 08:29, in 8 to 10 mph winds. The launch truck traveled about 100 ft past the bubble position to accomplish a very smooth payload release.

### 2. Tracking and Recovery

The system ascended on a SSE course to reach flow equilibrium above a point 4 miles west of Red Wing, Minnesota, at 10:18 CDT. The float winds moved the system west above Belle Plaine, Minnesota, at 15:00 when descent began. Descent direction was generally ESE to a touchdown 3 miles south of Kenyon, Minnesota, at 17:21. Impact position was 62 miles south of the launch site. The two-man ground recovery crew was able to recover and return all equipment with no unusual problems.

## C. Flight Results

### 1. Balloon

The balloon design and material were identical to that used on the previous flight. Using 8% free lift the average rate of rise was 727 fpm. Maximum altitude recorded was 79,400 feet at 10:40 CDT. At 12:10, a slow descent was first noted; by 12:42, the system had descended to 76,000 ft. This altitude loss continued until 14:00, when the rate of descent dropped to 60 fpm between 69,000 and 66,500 ft for the remaining hour of the normal float period. Total time above the 76,000 ft level was 2-1/2 hours; the mean altitude during the total float period was approximately 76,300 ft.



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The exact reason for the loss of float altitude experienced on this flight is unknown. There are, however, two generally accepted causes of this reaction; helium temperature variation or direct helium loss. A temperature change can be caused by a variation of the radiant heat flux reaching the balloon from below. This radiation would vary with the time of day, but changes in the earth's surface color or cloud cover below the balloon would be more significant. A helium temperature increase due to increased earth radiation would cause a balloon to ascend if it was below its ceiling altitude or to valve-off helium if it was floating at ceiling. Conversely, a drop in radiant energy from below the balloon will cause the helium to lose lift and the system to descend. In the past, up and down movements of a floating balloon have been correlated with such things as cloud cover and surface color. On this flight, the movement was always downward with no recovery. The descent experienced here can be roughly correlated with cloud cover and surface conditions, but the magnitude of the decrease was much greater than would normally be expected. This descent could also be caused by a small leak. Small sections of the balloon material are easily stressed beyond their yield dimensions while the balloon is restrained by the launch platform under high velocity wind conditions. Small holes can later develop at these stretch points. Normally, a leaking balloon will descend very slowly at first and then accelerate. Since this balloon remained at nearly a constant altitude for about 2 hours, descended for 1-1/2 hours, and then remained at a fairly constant altitude again for 1 hour, neither of the two theories, alone, can satisfactorily explain the flight profile. The only possible conclusion is that both variations in radiation and a helium leak combined to cause the considerable altitude loss of this flight.



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## 2. Instrumentation

On this flight, the secondary temperature commutator operated properly, as did the suntracker, data cycling switch, and all other electronic components of the reference and telemetry system. Despite the precautions taken to prevent the interference found on the last flight, it appeared again on a few data channels. Fortunately, the magnitude of the interference was less than previously and correspondingly affected the printed digital readout to only a small degree. Secondary temperatures telemetered, and gondola temperature recorded were completely normal on this flight. The telemetered reference voltages were exceptionally stable and, in fact, were within plus or minus one count, or better, of the nominal calibration frequency on all channels throughout the entire flight.

The suntracker was again severely damaged on impact. Unit #1 had several bolts sheared on the vertical support brackets, the main elevation drive shaft and the solar cell mounting plate were bent, and several limit switches and actuators were crushed. The plywood mounting disc was completely smashed. Fortunately, the solar cells themselves suffered no apparent damage.

## IV. FLIGHT 3035

### A. Flight Preparations

#### 1. Project Personnel Assignments

(same as Flight 3033)

#### 2. Pre-Flight Checkout

Because of the interference present on some data channels on both preceding flights, Jet Propulsion Laboratories issued a "Technical Direction Memorandum" listing five steps to be taken in a special effort to eliminate the problem. The directive listed the following items:

1) Check new "T" cable against old cable for pin connections an interconnections.

2) Check for voltage spikes on the d-c power lines at the suntracker with the baro-transmitter on.

3) Check grounds and common signal returns.

4) Check harmonic content of 1.746 MHz baro-transmitter. If bad, repair or replace transmitter.

5) Install pressure switch to turn off beacon above 75,000 ft and a motor-operated cam to allow only one minute in ten minutes of baro-coder information.

A resisistance check of the new "T" cable and an older cable demonstrated that the new cable was wired according to print. Although the old cable was wired to operate properly, a discrepancy was located. An improper interconnection between the solar cell common and the electronics common was found. The original design calls out separate grounds so that the low level solar cell outputs will not be affected by any variation in current required by the electronics circuitry. Since the data and reference channels have been exceptionally stable on both preceding flights using the new cable (except those channels affected by system noise), no change was made in the cabling.

An oscilloscope was used to check all power leads at the top end of the balloon cable for voltage transients or noise. Noise was seen on the power leads to the data stepping switch. These leads are in parallel with those supplying power to the baro-transmitter and the noise could be correlated with the keying of this transmitter. The noise was seen only when the transmitter power was off and it was traced directly to the altitude code drum drive motor. This drive motor ran continuously but induced brush noise on the power line only when the transmitter was off. During transmitter on time, the noise was swamped out or filtered by the transmitter. This motor was replaced by another type having an internal radio-noise filter which eliminated the interference. Both high- and low-impedance paths were found from the solar-cell modules to the suntracker plate. A resistance of only 15 was measured from the thermistor supply voltage lead to the plate; a resistance of 160,000 was measured from the sky-brightness experiment module to the plate. In order to eliminate possible ground loop currents within this low-level circuitry, these modules were isolated with polyethylene tape and nylon screws.

The output waveform of the baro-transmitter was viewed with an oscilloscope to determine the amount of distortion. This test indicated that this transmitter's harmonic content was equal to or less than other transmitters of this type. The transmitter was thus flown on this flight without change.

A motor-driven timer and a pressure switch were installed in the power lead of the baro-transmitter so that the unit would be on continuously below 75,000 ft and be turned off above this altitude, except for a one-minute on period every ten minutes. The nine minutes off time would allow noise-free data recording over 90% of the time; the one-minute on time was required in order to monitor float altitude and obtain a radio direction fix on the system, if necessary.

The reference voltage check, modulation check, on sun sensitivity check, primary and secondary temperatures check, and telemetry transmitter check showed the system to be operating perfectly. A sky brightness experiment was installed on the tracker using two solar cell output channels and the temperature reference channel. A thermistor on this experiment was calibrated with the primary temperature system in place of the standard reference resistor previously flown. The suntracker flown on the first flight had been repaired and an anti-backlash elevation drive gear installed to improve tracking accuracy. The initial on-sun checkout indicated proper operation, but when the tracker was installed for the system on-sun test its mechanical alignment was off center. Suntracker alignment was reset, the checkout repeated, and the system was judged ready to fly.

## B. Field Operation

### 1. Launch

Launch preparations for Flight 3035 were cancelled at 06:30 CDT on 10 August 1966, because of cloud cover and a forecast of broken cloud cover through the day. On 12 August, launch preparations began on schedule. The system layout began at 07:15 with two miles per hour wind. The only problem encountered during pre-launch preparation was a severe crack in the plywood tracker disc which occurred as inflation began. The disc was quickly taped and padded to prevent balloon damage. Final testing demonstrated that all components were operating properly and that the data was interference free. Launch was smoothly accomplished at 08:53 in six to eight miles per hour winds.

### 2. Tracking and Recovery

The systems course was east-southeasterly until reaching float altitude at 10:35 CDT over Burkhardt, Wisconsin. At float, the system moved west over Minneapolis to a position near Waverly, Minnesota, at the initiation of descent. The track was ENE on descent to impact three miles S of St. Francis, Minnesota, at 17:20. The aircraft observed the lower payload being dragged by the deflating balloon until it caught in nearby trees. The ground recovery crew found the site surrounded by water but they were able to enlist the help of the landowner with a high-axle truck to retrieve the equipment. Equipment damage was nil and the equipment was returned to the plant that evening.

## C. Flight Results

### 1. Balloon

The balloon was identical to that used on the preceding two flights. The rate of rise averaged 795 fpm to achieve a float altitude of 79,000 ft. Maximum recorded altitude was 79,400 ft and minimum altitude was 77,700 ft during the normal floating period. The balloon remained above 76,000 ft for a period of 4-1/2 hours.

### 2. Instrumentation

All components of the tracking-telemetering system performed flawlessly throughout the flight. There were no minor discrepancies; the received data was very stable and clean. There was no interference--even when the baro-transmitter was operating--during the floating period. All telemetered reference voltages were again within plus or minus one count( 0.1%) of the nominal calibration frequency during the entire float duration. Considering all aspects of the operation, this flight was the best of the series to date.

## V. FLIGHT 3037

### A. Flight Preparation

#### 1. Project Personnel Assignments

(Same responsibilities as Flight 3035, except L. Nelson assisted in ground recovery.)

#### 2. Pre-Flight Checkout

Suntracker #1 was set up and checked out for use on this 120,000-ft flight. During final checkout, an intermittent limit switch was located and replaced; a lock-up condition was eliminated by narrowing the slot of the acquisition solar sensor window.

In order to accurately monitor flight altitude at the height expected on this flight, a different sensor was required. A Litton model B-58 altitude transmitter was selected because it uses an ionization chamber to sense pressure/density and is capable of high resolution at extreme altitudes. Variations in pressure-altitude as small as 100 ft at 120,000 ft are readable using this unit. This transmitter features a standard motor-driven code drum for low-altitude use. The motor used is identical to the one used on the last flight; the transient suppressed keying relay and the line mounted RF chokes were also used. The B-58 contains an internal cycle switch and was wired to provide a transmitter off time of 20 sec (seconds) every 80 sec throughout the flight.

### B. Field Operation

#### 1. Launch

This launch was cancelled on 25 August due to poor weather, but it was rescheduled for the following day. Preparations began at 05:00 CDT on 26 August with calm winds and a clear sky. Inflation was started at 07:20 and the tracker assembly was lifted into its flight position on this larger balloon very smoothly. Inflation was halted when it was noticed that the uppermost descent gasport which was 30 ft from the ground was taped shut. The tape and packing were used to protect the balloon material from damage when in the shipping box and were not seen before inflation as they were folded under the balloon. A crane was called in order to reach the door, and in the meantime, a long pole was used to attempt to pull the tape and packing away. Fortunately, after a 45-minute effort, the tape and packing were sufficiently pulled away with the pole. During this effort, the wind velocity increased to rule out the use of the crane and to greatly increase the effort required with the pole. Inflation was completed during the effort and launch was completed without incident at 08:25. The bubble downwind dynamic launch technique with the lower payload mounted on the front of the launch truck was used on this flight as on all previous launches of this series. The fact that this balloon was larger in diameter by a factor of nearly three than previously used balloons presented no special inflation or launch problems.

### 2. Tracking and Recovery

The system drifted generally SW and was over Spring Valley, Wisconsin, when achieving float. Float winds returned the system to the northwest, to the vicinity of North Branch, Minnesota, at 15:00 CDT; the beginning of system descent. The system descended N and then at lower altitude drifted southeast to impact in a pasture eight miles N of Amery, Wisconsin, at 18:59. The balloon opened on impact and laid over some trees suspending the suntracker assembly about 20 ft in the air. The equipment was not damaged and the only recovery problem was in removing the balloon material from the trees. A farm tractor was rented to pull the balloon tapes down and in that manner most of the balloon material was removed from the trees. The crew and equipment returned early the following morning.

C. Flight Results

1. Balloon

This 200-ft diameter balloon was designed to carry the same JPL payload to an altitude of 120,000 ft and to provide a system descent rate, using only one-way valves, sufficient to bring the system down safely before sunset. See Appendix pages A-3 and A-4 for the operational specification sheet and the load-altitude curve on this design. This balloon was similar in size to the first attempted 120,000-ft flight (2610, launched 8 November 1962) but featured a much improved apex design to prevent excess balloon material from coming near the top mounted payload or into the field of view of the suntracker. The top end fitting on this design was a 21-inch plate hoop and ring assembly with the balloon gores and load tapes overlapped around the hoop and taped back a distance of about 3 ft. The result was a heavily reinforced top section around and extending out from the 6-ft diameter plywood mounting disc. During inflation and launch, there was absolutely no billowing of material or any top section deformaties whatsoever.

Using 9% free lift, the average rate of rise was 720 fpm to 93,500 ft where a timed 1% ballast drop was made in order to maintain the ascent rate. Following the drop, the rate increased to 810 fpm to 102,500 feet, then it slowed up somewhat above that level. The overall rate of rise was 720 feet per minute to 119,500 feet achieved at 11:11 CDT. The system penetrated the 114,000-ft level at 11:02 and remained above that altitude for 4 hours and 21 minutes. The maximum variation in float altitude was only 2100 feet throughout the floating period.

Descent began at 15:00 CDT when 3 six-inch gasports were opened by the timer. Initial descent rate was only 200 fpm, but it increased and eventually reached 1100 fpm from 40,000 ft to the surface. The overall descent rate was 493 fpm from 117,800 ft to the surface.

## 2. Instrumentation

The suntracker, stepping switch, FM transmitter and high-resolution altitude transmitter performed properly throughout the flight. After the numerous "fixes" on the data interference problem and the perfect results obtained on Flight 3035, no trouble was anticipated on this flight. Unfortunately, as the balloon reached float altitude, data noise similar to that obtained on the first two flights was observed and correlated with the on-off keying of the B-58 altitude transmitter. Unlike the earlier problem, however, the noise was apparent only at altitude and only on channels 19, 21 and 22. The interference was continuous at altitude except when the 20-second-off period of the B-58 occurred with the data switch on the affected three channels.

Another variation from the previous flight was a greater variation in calibration voltage frequencies. The 100-mv frequency shifted a maximum of +6 hertz during the float period; the shift in the other references was proportionally less and the zero shift was nil. Percentage wise, the frequency drift was small (less than 1%) and may be compensated for when reducing the data. The cause of the drift was the high instrumentation temperatures reached at the higher altitude as seen by the secondary temperature telemetry (see Appendix page A-9 By the end of float, the voltage controlled oscillator compartment had reached a temperature of +57 C, box #2 temperature +54 C, and box #1 temperature +67 C. Although the temperature rise error was not large and did no permanent damage, future high-altitude flights will require a modification of the thermal characteristics of the instrumentation containers.



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## VI. CONCLUSIONS AND RECOMMENDATIONS

The three 77 ft and the one 200 ft diameter balloons flown this year performed successfully in that each reached its ceiling altitude, floated, and descended in the expected manner. One of the 77 ft balloons, however, did not maintain the minimum floating altitude (76,000 feet) for the total required period (11:00 to 15:00 CDT). The probable reasons for this deviation have been discussed in Section III. C. To reduce the chance of this happening during future flights, two precautions can be taken. First, better meteorological information on predicted surface wind velocity will be sought to minimize the possibility of balloon damage during inflation and launch. Second, further effort will be made to reduce system weight in order to achieve a higher float altitude so that a larger altitude drop can be tolerated before reaching the specified minimum. The volume of each of the three small balloons was increased by 14,328 cubic feet this year to increase the float altitude. Unfortunately, the battery pack weight also increased offsetting the expected altitude advantage.

The suntrackers operated perfectly on all flights. The modifications made on the units during this program resulted in better performance over a wide voltage range, and minor improvement in pointing accuracy because of a reduction in mechanical hysteresis. The regulator circuitry that prevented battery voltage variations from affecting tracker sensitivity and stability has been previously discussed (see Section II. C). The units suffered severe mechanical damage on surface impacts this year. Repairs were successfully made but mechanical tolerances in the drive trains are building up to an objectional level. Anti-backlash elevation drive gears were installed midway through the flight schedule. They improved performance but not to a large degree as most of the free play was within the gear train of the drive motors. If continued use of the same units is desired on future programs, it is recommended that new drive motors, or at least new gear trains be installed. It is also recommended that slip clutches be installed on the elevation motor drive to further reduce backlash and minimize drive train damage on impact. If desired, Litton would be glad to issue a proposal to JPL for a completely redesigned, improved suntracker for use on future programs.

Electrical interference within the airborne telemetry system was a continuing problem on three of the four flights. The cause of the interference was determined to be the baro-transmitter, but the exact mechanisms that caused the interference to affect certain data channels on certain flights could not be explained. In order to minimize and hopefully eliminate this interference in the future, several steps are proposed. Until it is definitely established that the noise has been eliminated a beacon turn-off timer will be used as flown on Flight 3035. In an attempt to reduce system weight and eliminate several circuit paths that we suspect are conducting the noise, it is planned to replace the wet cell battery pack with several separate alkaline-magnesium dry battery packs. In this manner the baro-transmitter, stepping switch and tracker can be completely isolated from the telemetry electronics circuitry. The alkaline dry cells proposed feature high current drain, good low temperature performance and comparatively low cost. Although the battery cost per flight will increase slightly, the weight saving will allow a 2000 ft increase in float altitude of the 77 ft balloon in addition to the circuit isolation. The initial cost increase should be offset by elimination of the labor time now used to recharge and test the wet cell battery between each flight.

Temperature rise of the top mounted electronic circuity proved to be a problem on the 120,000 ft flight. Although a circuit redesign could reduce the amount of system drift a much simpler fix is contemplated. No change is needed for flights achieving less than 100,000 ft altitude. Above that level a sun shield will be installed above the electronics section but below the tracker plate. By proper design and coloring this shield would prevent sun radiation heating of the enclosed circuitry yet not interfere with or cause reflections on the suntracker.

Litton again looks forward to another opportunity to satisfy the demanding requirements of Jet Propulsion Laboratory in the areas of high performance airborne mechanical and electronic systems and balloon operations.

## APPENDIX

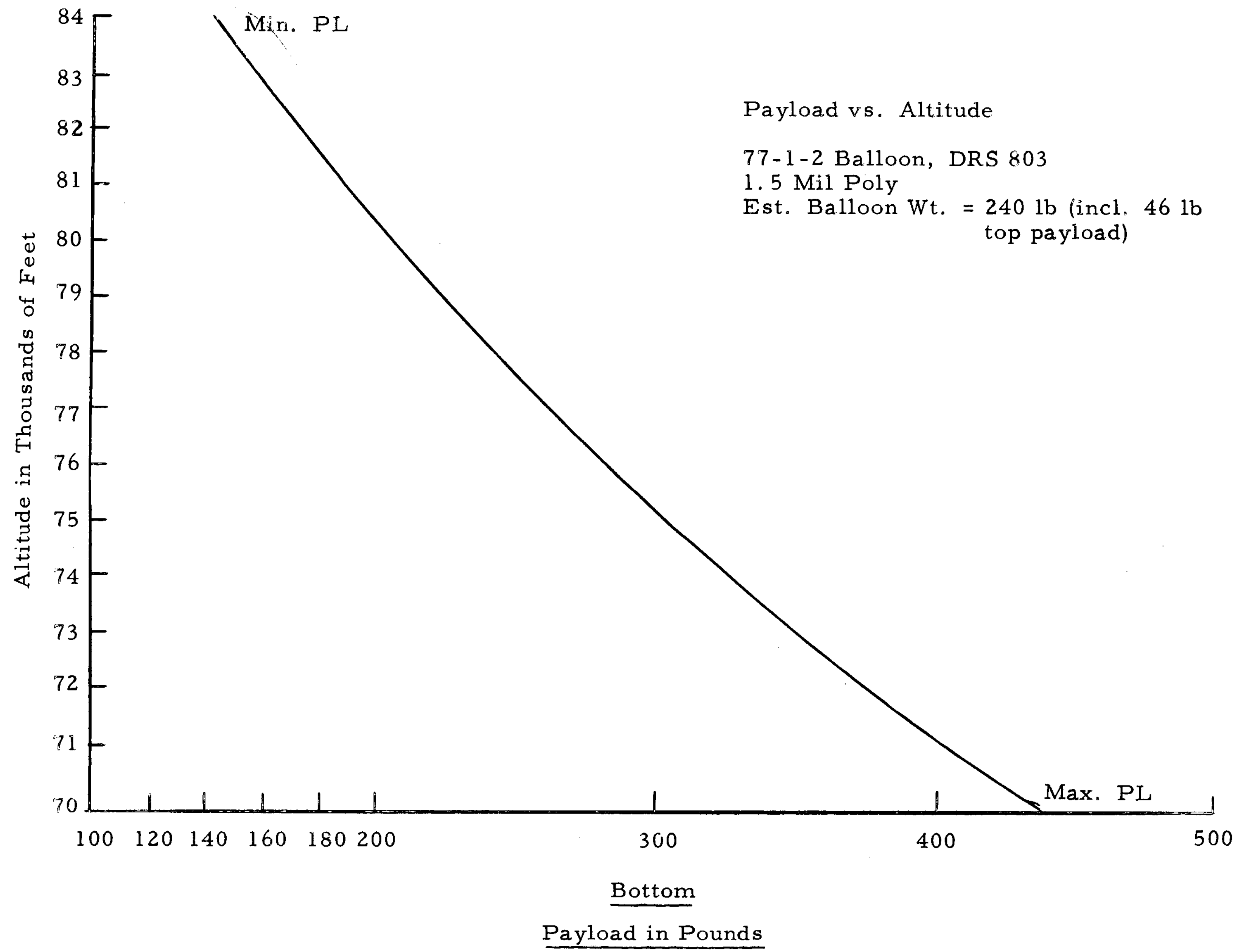
### Flight Data

Operational Specification Sheet
(for 77-1-2 balloon)

| | | |
|---|---|---|
| Fabric Parameter ($\Sigma$) - - - - - - - - - - - - - - - - - - | | 0.05 |
| Payload (Design) - - - - - - - - - - - - - - - - - - - - - | | 219 lb + 46 lb Top PL |
| Material (Balloon Wall and Duct) - - - - - - - - - - - | | 1.5 mil Polyethylene |
| Volume (Theoretical) - - - - - - - - - - - - - - - - - - | | 189,113 $ft^3$ |
| Surface Area (Estimated) - - - - - - - - - - - - - - - - | | 15,996 $ft^2$ |
| Inflated Height - - - - - - - - - - - - - - - - - - - - - - | | 86.25 ft |
| Deflated Length (Gore Length) - - - - - - - - - - - - - | | 113.5 ft |
| Load Tapes - - - - - - - - - - - - - - - - - - - - - - - - | | None |
| Fittings; top - - - - - - - - - - - - - - - - - - - - - - - | | Inverted EV-13, 230822 |
| Fittings; bottom - - - - - - - - - - - - - - - - - - - - - | | 4 in. diameter integral |
| Number of Ducts - - - - - - - - - - - - - - - - - - - - - | | Two |
| Location of Duct - - - - - 10 sq ft each | Lo-Duct | 40 ft from base |
| | Hi-Duct | 35 ft 6 in. from top apex |
| Inflation Tube - - - - - - - - - - - - - - - - - - - - - - - | | 20 in. layflat x 3 mil x 75 ft long |
| Inflation Attachment - - - - - - - - - - - - - - - - - - | | 20 ft from top apex, 233399 |
| Destruction Device - - - - - - - - - - - - - - - - - - - - | | Prima Cord |
| Descent Valves - - - - - - - - - - - - - - - - - - - - - - | | One located 34 ft 6 in. from top apex |
| Estimated Balloon Weight - - - - - - - - - - - - - - - | | 185 lb (incl. 25 lb of cable) |
| Engineering Specification Sheet - - - - - - - - - - - | | 234654 |
| DRS - - - - - - - - - - - - - - - - - - - - - - - - - - - - - | | 803 |
| Load Altitude Curve - - - - - - - - - - - - - - - - - - - | | 233521 |

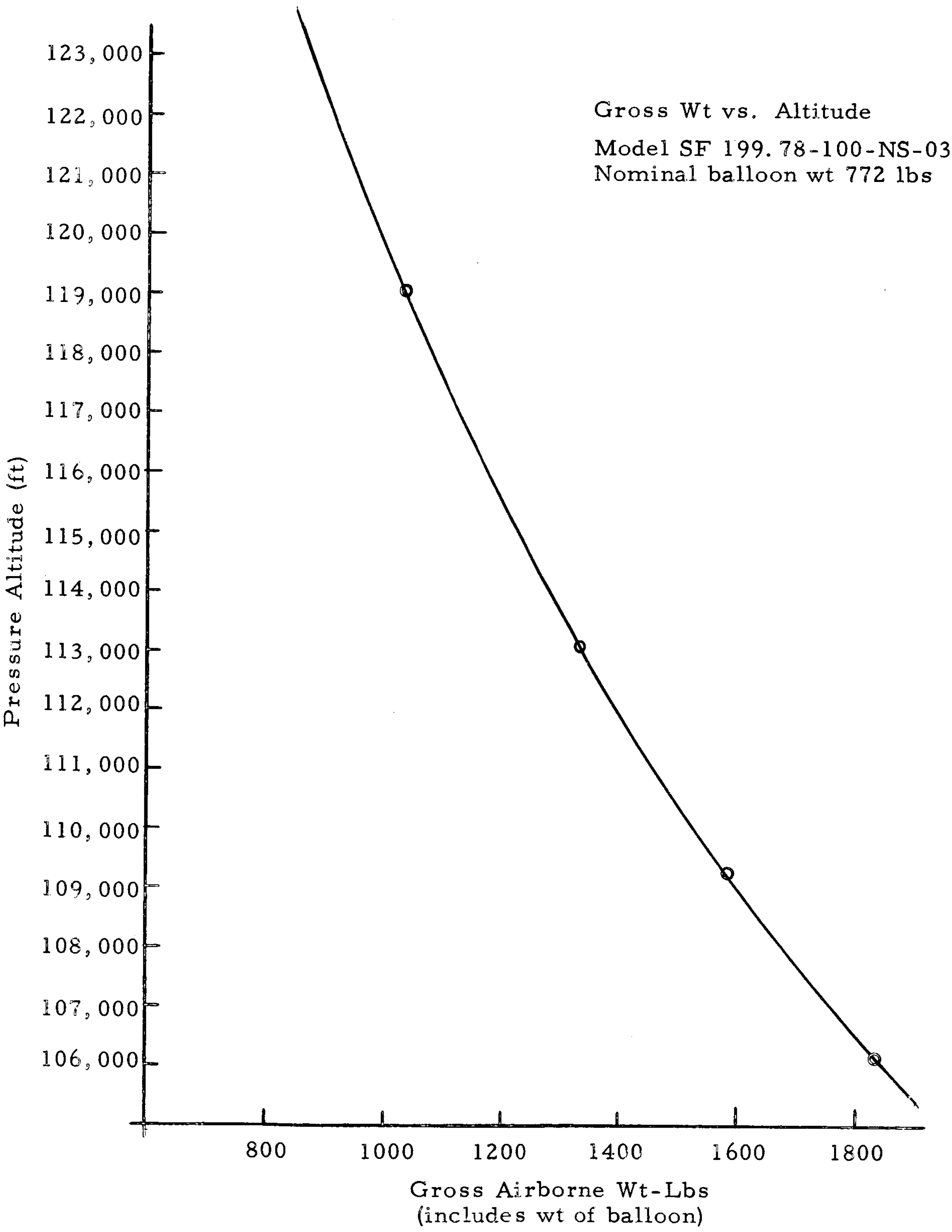


30


Payload vs. Altitude
77-1-2 Balloon, DRS 803
1.5 Mil Poly
Est. Balloon Wt. = 240 lb (incl. 46 lb top payload)
Min. PL
Max. PL
Altitude in Thousands of Feet
84
83
82
81
80
79
78
77
76
75
74
73
72
71
70
100 120 140 160 180 200 300 400 500
Bottom
Payload in Pounds

Operation Specification Sheet
(for SF-199.78-100-NS-03 balloon)

| | |
|---|---|
| Fabric Parameter (Σ) - - - - - - - - - - - - - - - - - - | 0,40 |
| Payload (Design) - - - - - - - - - - - - - - - - - - - | 245 lb to 120,000 ft |
| Material (Balloon Wall and Duct) - - - - - - - - - - - | 1.0 mil S.F. Polyethylene |
| Volume (Theoretical) - - - - - - - - - - - - - - - - - - | 2,940,000 $ft^3$ |
| Surface Area (Estimated) - - - - - - - - - - - - - - - | Not available |
| Inflated Height - - - - - - - - - - - - - - - - - - - - - - | 152 ft |
| Deflated Length (Gore Length) - - - - - - - - - - - - | 271 ft |
| Load Tapes - - - - - - - - - - - - - - - - - - - - - - - | 300 lb |
| Fittings; top - - - - - - - - - - - - - - - - - - - - - - - | Plate Hoop and Ring - 21 in. I.D. |
| Fittings; bottom - - - - - - - - - - - - - - - - - - - - - | 4 in. I.D. Wedges and Collar |
| Number of Ducts - - - - - - - - - - - - - - - - - - - - | Three |
| Location of Duct - - - - - 25 sq ft each — Lo-Duct (2) | 100 ft from base |
| Location of Duct - - - - - 25 sq ft each — Hi-Duct | 235 ft from base |
| Inflation Tube - - - - - - - - - - - - - - - - - - - - - - | 20 in. layflat x 3 mil x 85 ft long |
| Inflation Attachment - - - - - - - - - - - - - - - - - - | 30 ft from top apex |
| Destruction Device - - - - - - - - - - - - - - - - - - - | Prima Cord |
| Descent Valves - - - - - - - - - - - - - - - - - - - - - | Three in hi-duct |
| Estimated Balloon Weight - - - - - - - - - - - - - - | 755 lb (incl. cable) |
| Engineering Specification Sheet - - - - - - - - - - | CO 1326 |
| DRS - - - - - - - - - - - - - - - - - - - - - - - - - - - - | 264 |
| Load Altitude Curve - - - - - - - - - - - - - - - - - - | 100381 |


Gross Wt vs. Altitude
Model SF 199.78-100-NS-03
Nominal balloon wt 772 lbs
Pressure Altitude (ft)
123,000
122,000
121,000
120,000
119,000
118,000
117,000
116,000
115,000
114,000
113,000
112,000
111,000
110,000
109,000
108,000
107,000
106,000
800
1000
1200
1400
1600
1800
Gross Airborne Wt-Lbs
(includes wt of balloon)

Final System Calibration Data

| Reference Calibration Levels | Flight 3033 | | Flight 3034 | | Flight 3035 | | Flight 3037 | |
|---|---|---|---|---|---|---|---|---|
| | Voltage (millivolts) | Frequency (cycles/sec) | Voltage (millivolts) | Frequency (cycles/sec) | Voltage (millivolts) | Frequency (cycles/sec) | Voltage (millivolts) | Frequency (cycles/sec) |
| 100 mv | 100.006 | 6846 | 100.004 | 6846 | 100.005 | 6844 | 100.006 | 6845 |
| 80 | 80.015 | 7070 | 80.013 | 7068 | 80.011 | 7067 | 80.015 | 7069 |
| 70 | 70.010 | 7179 | 70.008 | 7179 | 70.006 | 7179 | 70.008 | 7179 |
| 60 | 60.000 | 7290 | 59.997 | 7289 | 59.996 | 7289 | 59.998 | 7289 |
| 50 | 50.004 | 7400 | 50.000 | 7399 | 50.000 | 7389 | 50.000 | 7399 |
| 25 | 24.970 | 7670 | 24.964 | 7670 | 24.964 | 7669 | 24.966 | 7670 |
| 0 | 00.002 | 7936 | 00.001 | 7936 | 00.001 | 7935 | 00.001 | 7936 |

Telemetered Secondary Temperature Data; Flight 3033, 29 July 1966

| Time From Launch | Temperatures (in degrees C) | | | | |
|---|---|---|---|---|---|
| | V. C. O. | Disc | Box #1 | Tracker | Box #2 |
| L-1/2 hr | +46 | +17 | +27 | +19 | +26 |
| L (08:58 CDT) | | | | 22 | |
| L+1/2 | | | | 17 | |
| L+1 | | | | 1 | |
| L+1-1/2 | | | | 4 | |
| L+2 | | | | 17 | |
| L+2-1/2 | | | | 24 | |
| L+3 | | | | 30 | |
| L+3-1/2 | | | | 31 | |
| L+4 | | | | 36 | |
| L+4-1/2 | | | | 36 | |
| L+5 | | | | 36 | |
| L+5-1/2 | | | | 35 | |
| L+6 | | | | 36 | |
| L+6-1/2 | | | | 31 | |
| L+7 | | | | 8 | |
| L+7-1/2 | | | | -14 | |
| L+8 | | | | - 1 | |
| L+8-1/4 | | | | + 6 | |

Telemetered Secondary Temperature Data; Flight 3034, 4 August 1966

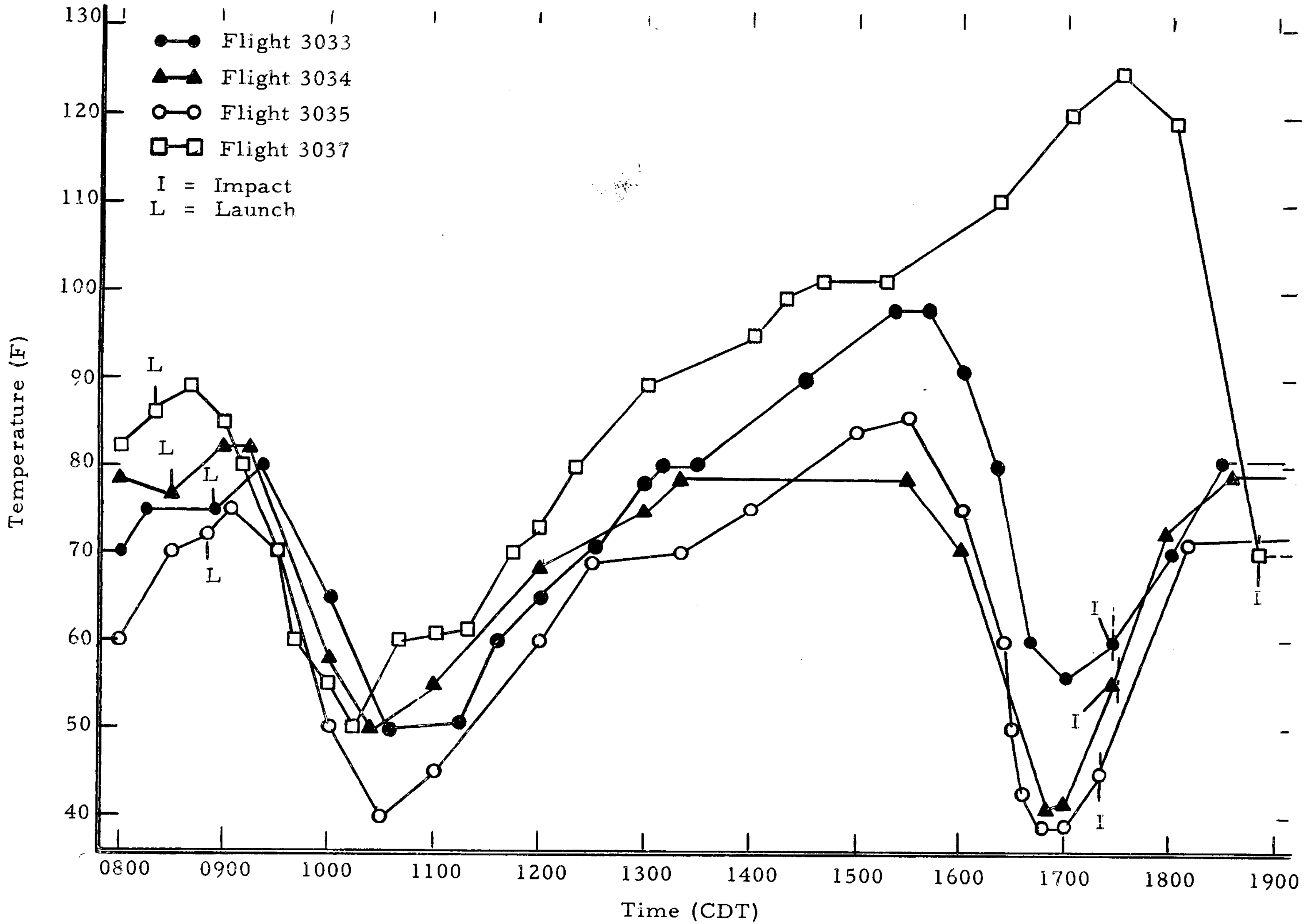
| Time From Launch | Temperatures (in degrees C) | | | | |
|---|---|---|---|---|---|
| | V. C. O. | Disc | Box #1 | Tracker | Box #2 |
| L-1/2 hr | +47 | +21 | +36 | +21 | +30 |
| L (08:29 CDT) | 49 | 19 | 36 | 22 | 34 |
| L+1/2 | 49 | - 7 | 41 | 19 | 33 |
| L+1 | 47 | -35 | 29 | 0 | 26 |
| L+1-1/2 | 47 | -17 | 21 | 0 | 22 |
| L+2 | 46 | 1 | 22 | 8 | 22 |
| L+2-1/2 | 47 | 11 | 32 | 19 | 26 |
| L+3 | 47 | 14 | 39 | 24 | 26 |
| L+3-1/2 | 47 | 12 | 45 | 28 | 29 |
| L+4 | 47 | 10 | 45 | 28 | 30 |
| L+4-1/2 | 47 | 13 | 45 | 29 | 33 |
| L+5 | 47 | 5 | 47 | 29 | 36 |
| L+5-1/2 | 47 | - 2 | 47 | 29 | 34 |
| L+6 | 47 | - 2 | 48 | 26 | 32 |
| L+6-1/2 | 47 | 3 | 44 | 22 | 32 |
| L+7 | 47 | - 8 | 41 | 19 | 31 |
| L+7-1/2 | 46 | -27 | 33 | 1 | 26 |
| L+8 | 46 | -21 | 27 | -11 | 22 |
| L+8-1/2 | +46 | + 8 | +29 | + 8 | +22 |

Telemetered Secondary Temperature Data; Flight 3035, 12 August 1966

| Time From Launch | Temperatures (in degrees C) | | | | |
|---|---|---|---|---|---|
| | V. C. O. | Disc | Box #1 | Tracker | Box#2 |
| L-1/2 hr | +46 | +15 | +36 | +17 | +29 |
| L (08:53 CDT) | 47 | 15 | 41 | 18 | 31 |
| L+1/2 | 47 | -21 | 39 | 14 | 30 |
| L+1 | 47 | -27 | 29 | - 1 | 25 |
| L+1-1/2 | 47 | -16 | 21 | 2 | 21 |
| L+2 | 47 | 3 | 25 | 13 | 24 |
| L+2-1/2 | 47 | 4 | 31 | 19 | 26 |
| L+3 | 47 | 5 | 34 | 24 | 30 |
| L+3-1/2 | 47 | 3 | 42 | 27 | 28 |
| L+4 | 47 | 6 | 45 | 27 | 28 |
| L+4-1/2 | 47 | 9 | 47 | 29 | 30 |
| L+5 | 47 | 8 | 47 | 30 | 32 |
| L+5-1/2 | 48 | 7 | 44 | 31 | 36 |
| L+6 | 48 | 8 | 44 | 32 | 36 |
| L+6-1/2 | 48 | -12 | 42 | 26 | 36 |
| L+7 | 47 | -28 | 40 | 10 | 30 |
| L+7-1/2 | 46 | -31 | 28 | -15 | 24 |
| L+8 | +46 | + 1 | +27 | 0 | +22 |

Telemetered Secondary Temperature Data; Flight 3037, 26 August 1966

| Time From Launch | Temperatures (in degrees C) | | | | |
|---|---|---|---|---|---|
| | V. C. O. | Disc | Box #1 | Tracker | Box #2 |
| L-1/2 hr | +46 | +16 | +37 | +18 | +28 |
| L (08:25 CDT) | 47 | 19 | 39 | 19 | 29 |
| L+1/2 | 46 | -14 | 36 | 13 | 28 |
| L+1 | 45 | -28 | 23 | - 6 | 21 |
| L+1-1/2 | 46 | - 3 | 18 | - 6 | 21 |
| L+2 | 46 | 18 | 20 | 6 | 21 |
| L+2-1/2 | 47 | 29 | 26 | 17 | 24 |
| L+3 | 47 | 45 | 36 | 29 | 31 |
| L+3-1/2 | 48 | 50 | 41 | 36 | 37 |
| L+4 | 49 | 55 | 45 | 41 | 42 |
| L+4-1/2 | 50 | 57 | 57 | 44 | 45 |
| L+5 | 52 | 60 | 60 | 48 | 48 |
| L+5-1/2 | 54 | 60 | 60 | 50 | 52 |
| L+6 | 55 | 57 | 65 | 50 | 52 |
| L+6-1/2 | 57 | 57 | 67 | 54 | 55 |
| L+7 | 56 | 37 | 65 | 50 | 52 |
| L+7-1/2 | 54 | 31 | 62 | 42 | 45 |
| L+8 | 52 | 27 | 55 | 39 | 45 |
| L+8-1/2 | 49 | 19 | 50 | 34 | 42 |
| L+9 | 47 | 2 | 47 | 26 | 36 |
| L+9-1/2 | 47 | -28 | 35 | 11 | 32 |
| L+10 | 45 | -39 | 21 | -20 | 22 |
| L+10-1/2 | +45 | +18 | +21 | +13 | +21 |




Lower Payload Temperature Profiles

FLIGHT NO. 3033 DATE 29 JULY 1966

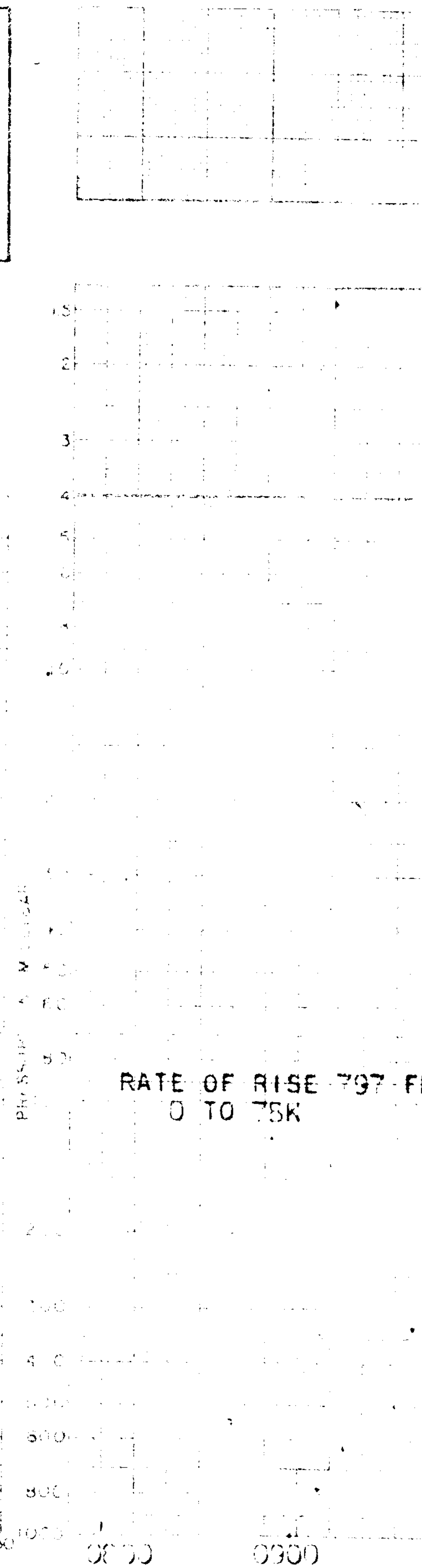
FOR JPL 79615

LOAD ON BALLOON 268 LBS

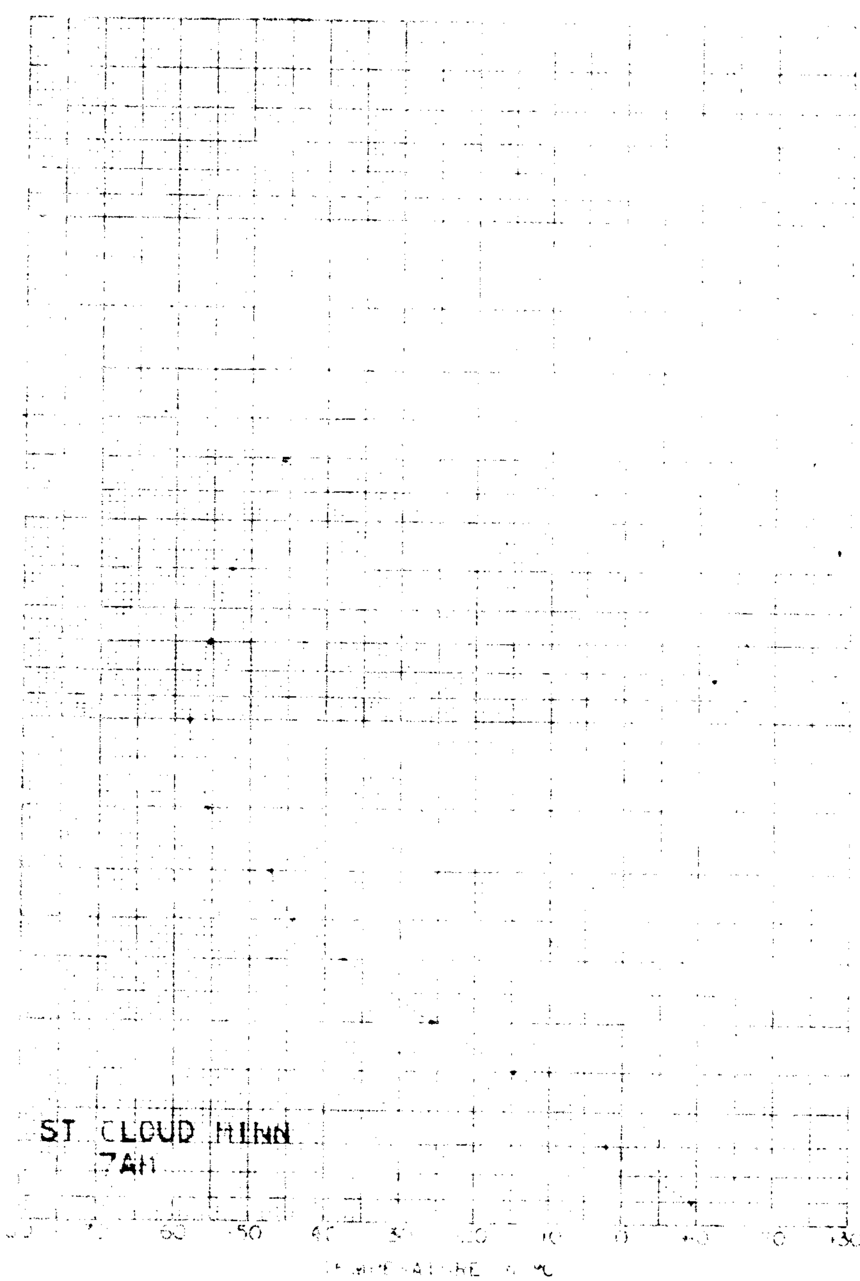
FREE LIFT 37 LBS 8%

| BALLOON TYPE | NUMBER | MATERIAL | WEIGHT |
| --- | --- | --- | --- |
| 77-1-1 | IDRS803 | 1.5 MIL | 194 LBS |

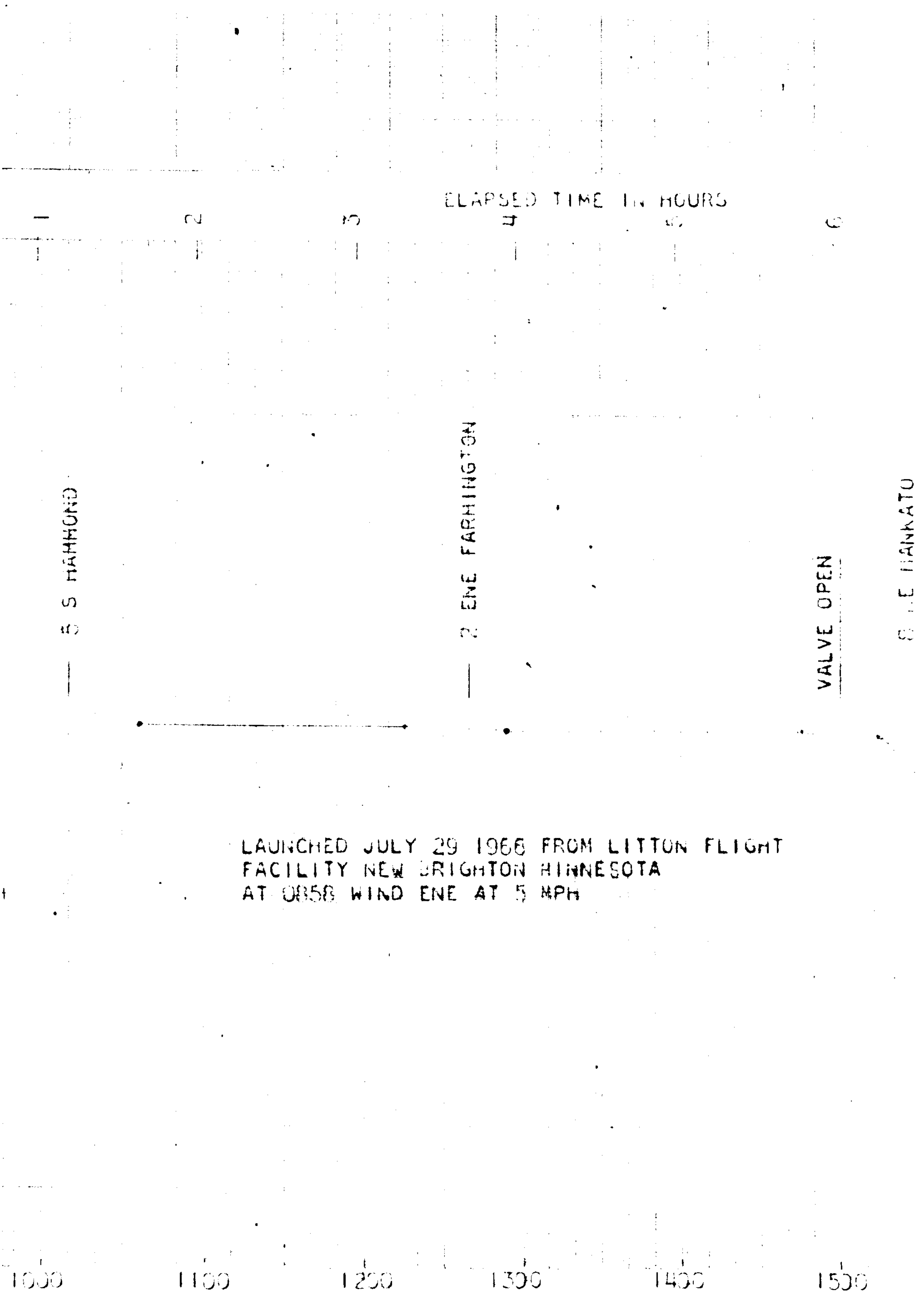
ALTITUDE DATA

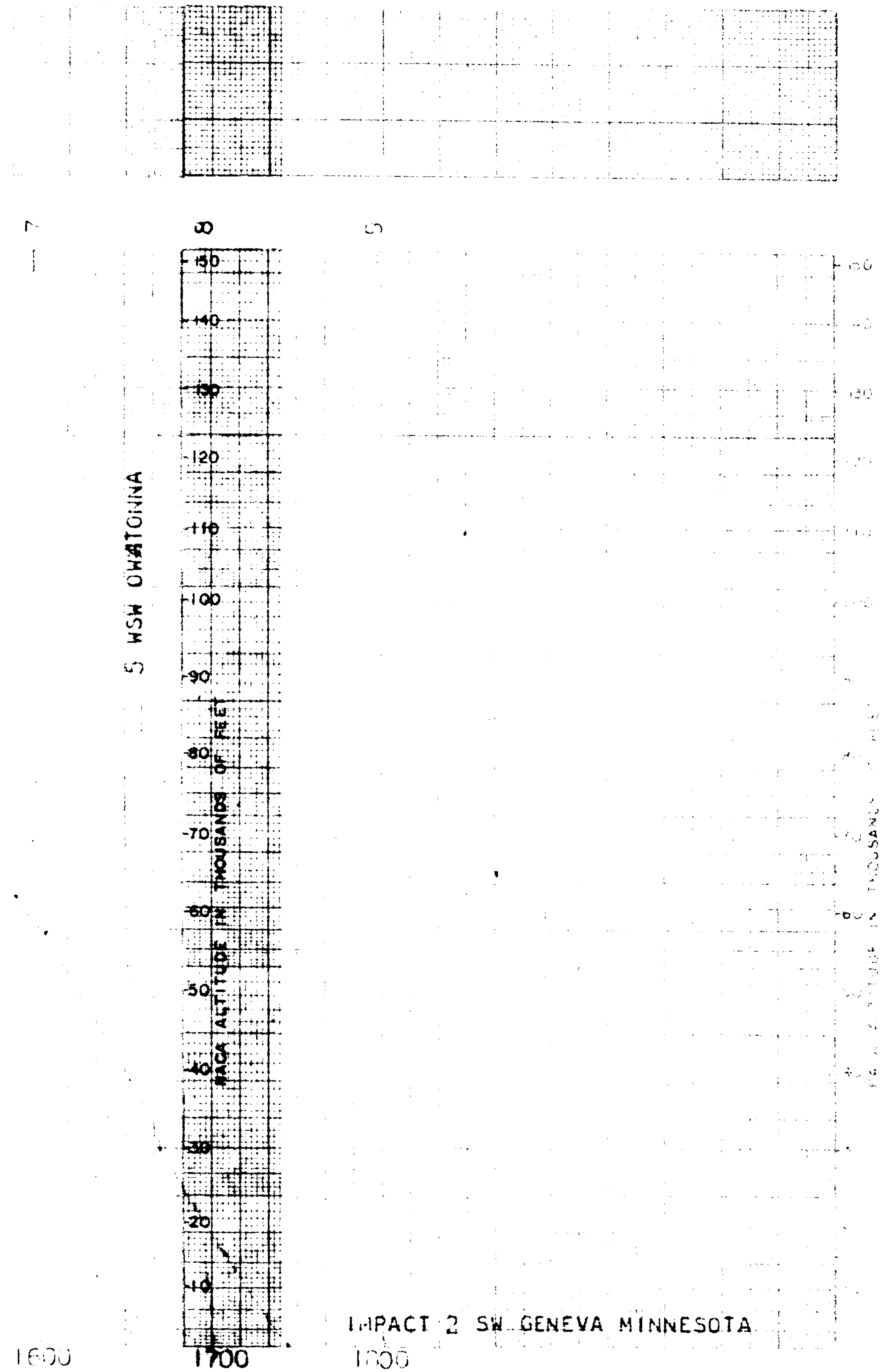



TEMPERATURE DATA




40-1


ELAPSED TIME IN HOURS
1
2
3
4
5
6
5 S HAMMOND
2 ENE FARMINGTON
VALVE OPEN
MANKATO
LAUNCHED JULY 29 1966 FROM LITTON FLIGHT
FACILITY NEW BRIGHTON MINNESOTA
AT 0858 WIND ENE AT 5 MPH
1000
1100
1200
1300
1400
1500


5 WSW OWATONNA
NACA ALTITUDE IN THOUSANDS OF FEET
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
7
8
9
IMPACT 2 SW GENEVA MINNESOTA
1600
1700
1800

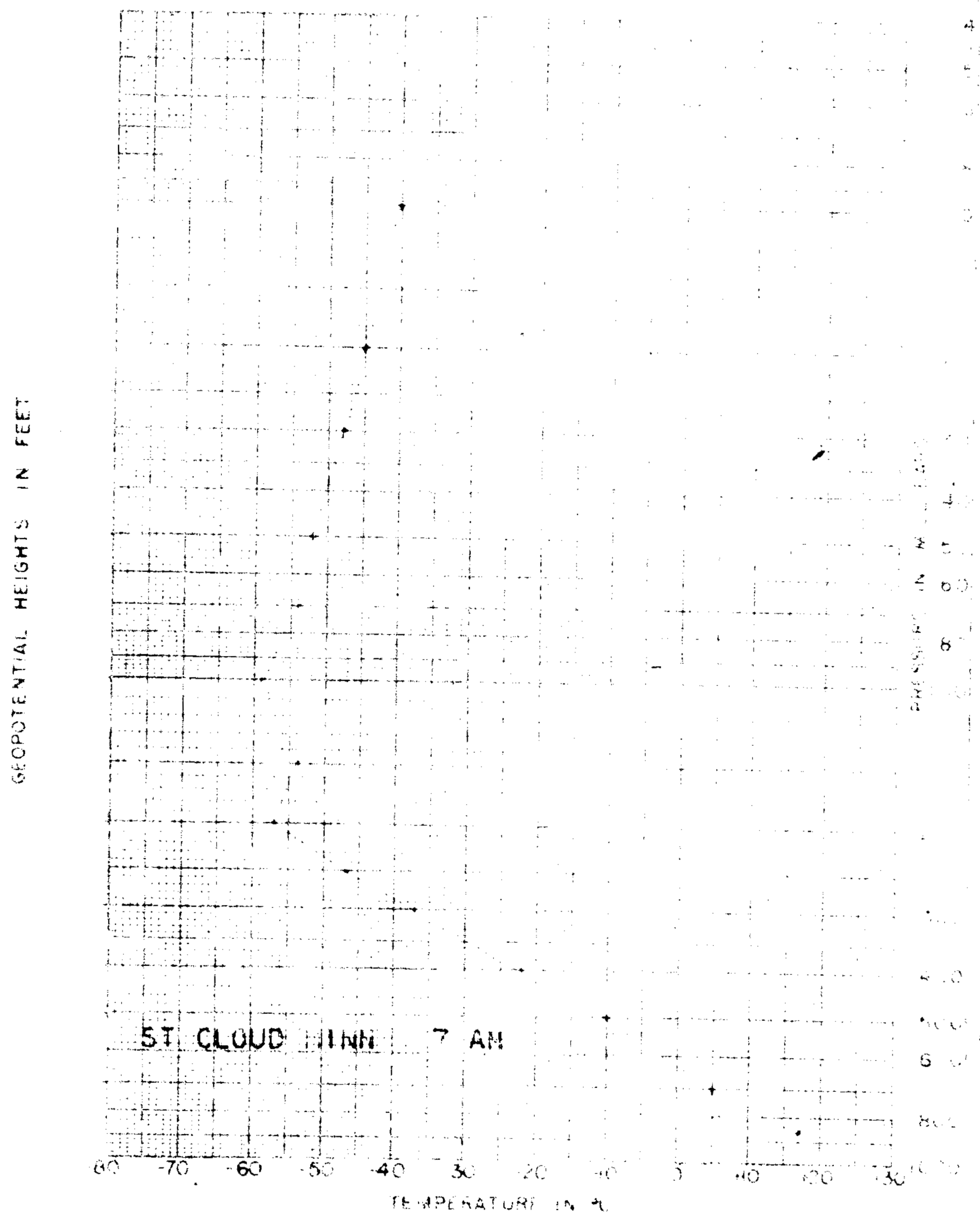
40-3

40

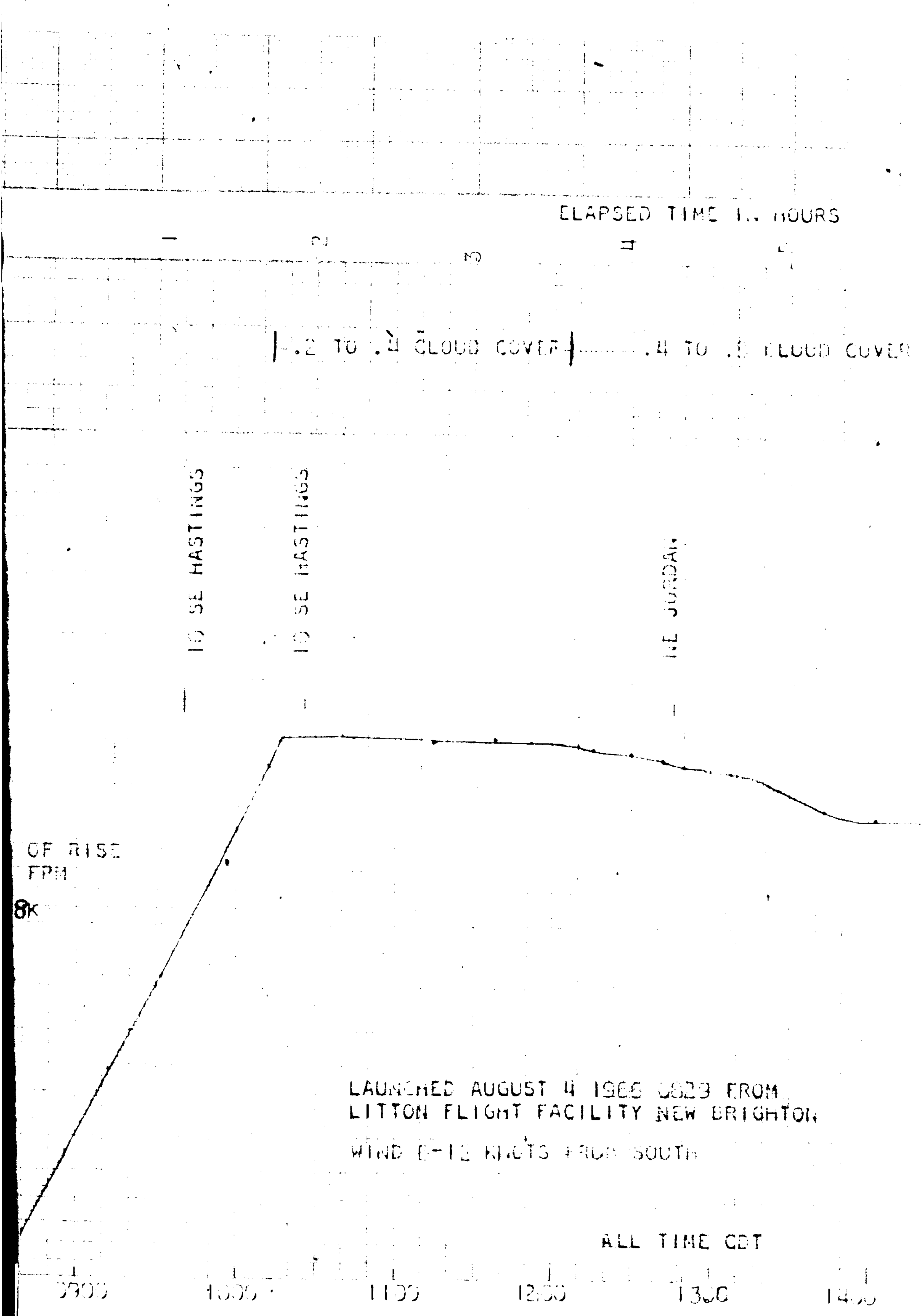
FLIGHT NO. 3034 DATE 8 AUG 1966
FOR JPL
LOAD ON BALLOON
FREE LIFT 36 LBS= 8 %
BALLOON TYPE NUMBER MATERIAL WEIGHT
77-1-1 1.5 LBS.

ALTITUDE DATA

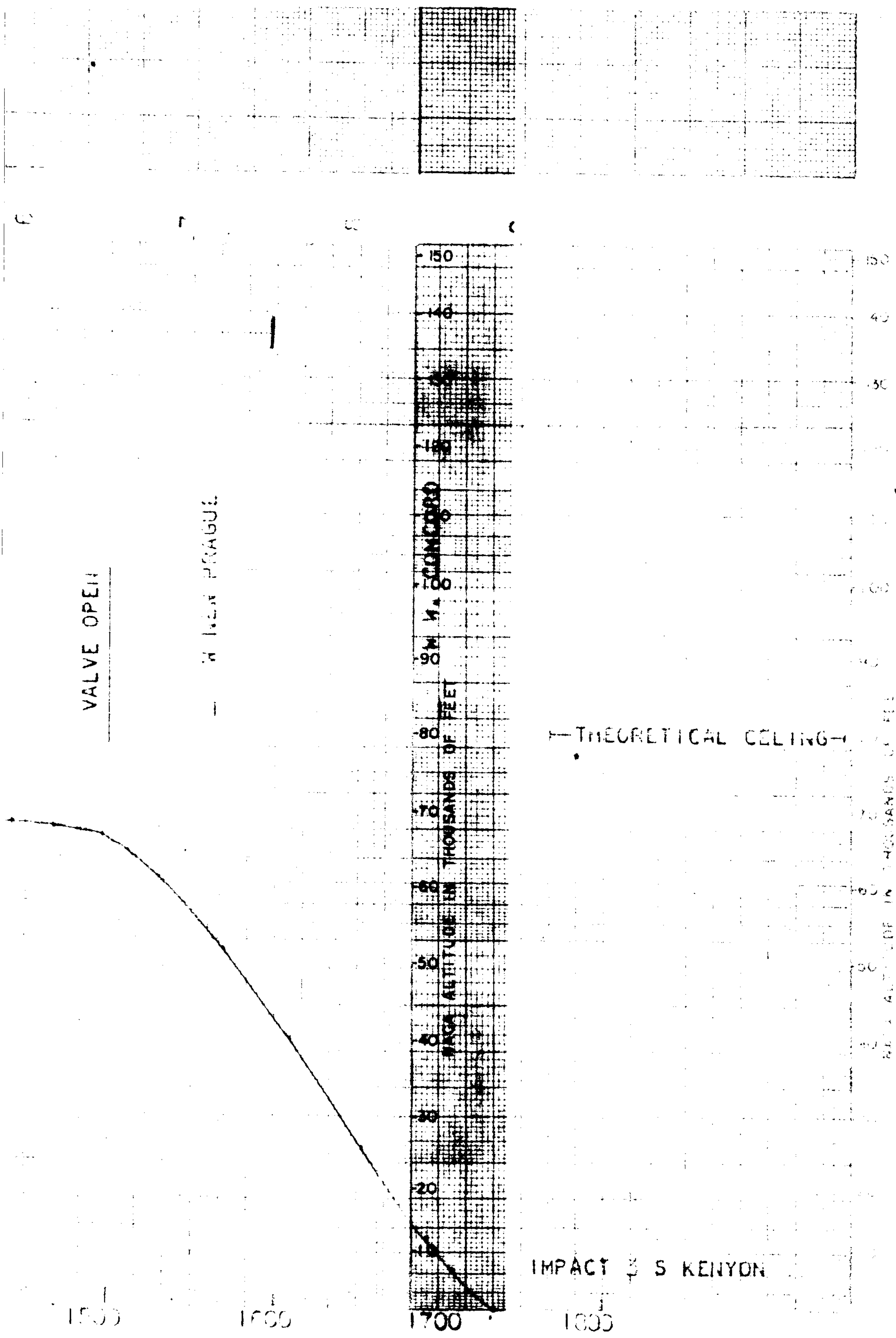
TEMPERATURE DATA




41-1



ELAPSED TIME IN HOURS
.2 TO .4 CLOUD COVER
.4 TO .8 CLOUD COVER
10 SE HASTINGS
10 SE HASTINGS
NE JORDAN
OF RISE
FPM
8K
LAUNCHED AUGUST 4 1966 0829 FROM
LITTON FLIGHT FACILITY NEW BRIGHTON
WIND 8-12 KNOTS FROM SOUTH
ALL TIME CDT
0900
1000
1100
1200
1300
1400

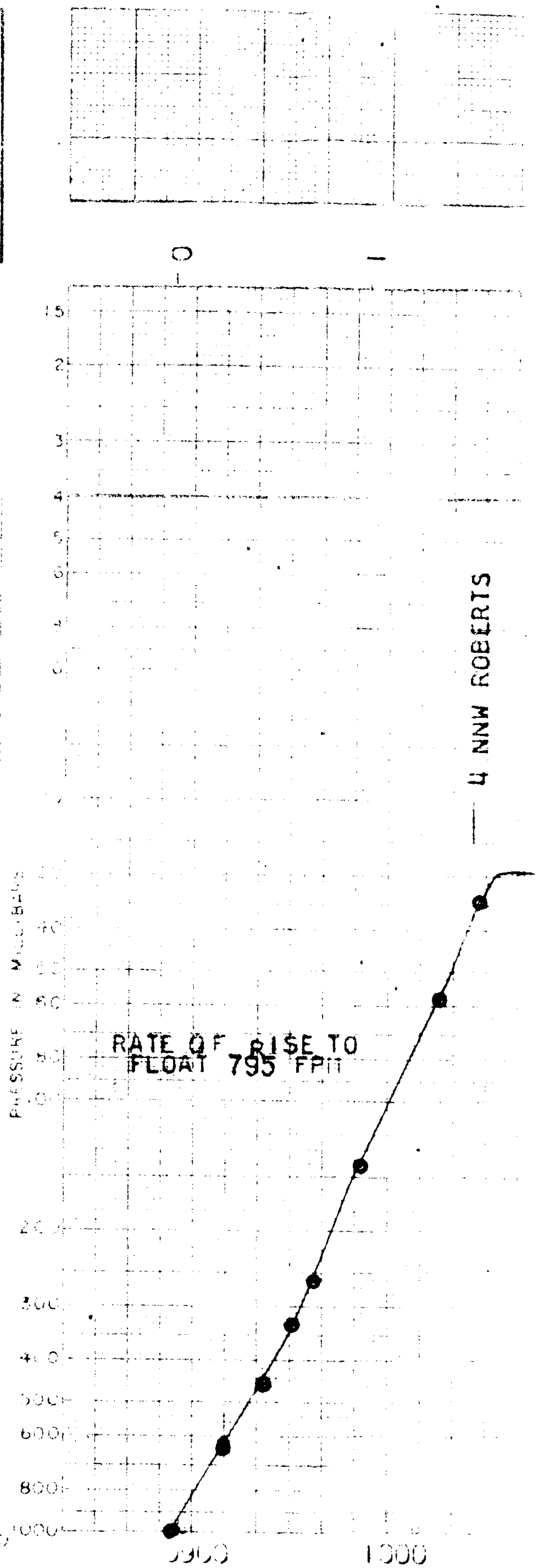

VALVE OPEN
W NEW PRAGUE
CONCORD
NACA ALTITUDE IN THOUSANDS OF FEET
150
140
100
90
80
70
60
50
40
30
20
10
THEORETICAL CEILING
IMPACT S KENYON
1500
1600
1700
1800

41·3

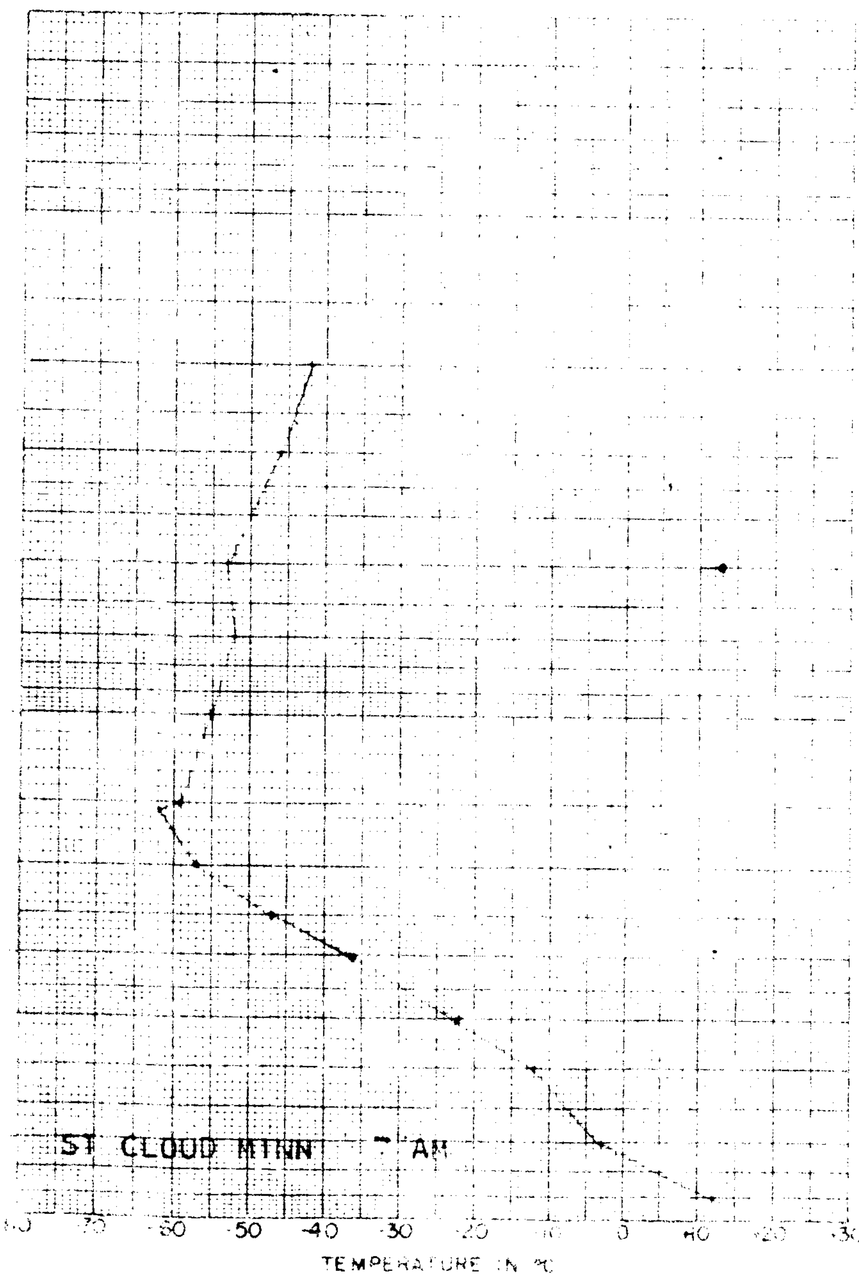
FLIGHT NO. 3035 DATE AUG 12-1966
FOR 59615
LOAD ON BALLOON 261 LBS
FREE LIFT 37 LBS= . 8 %

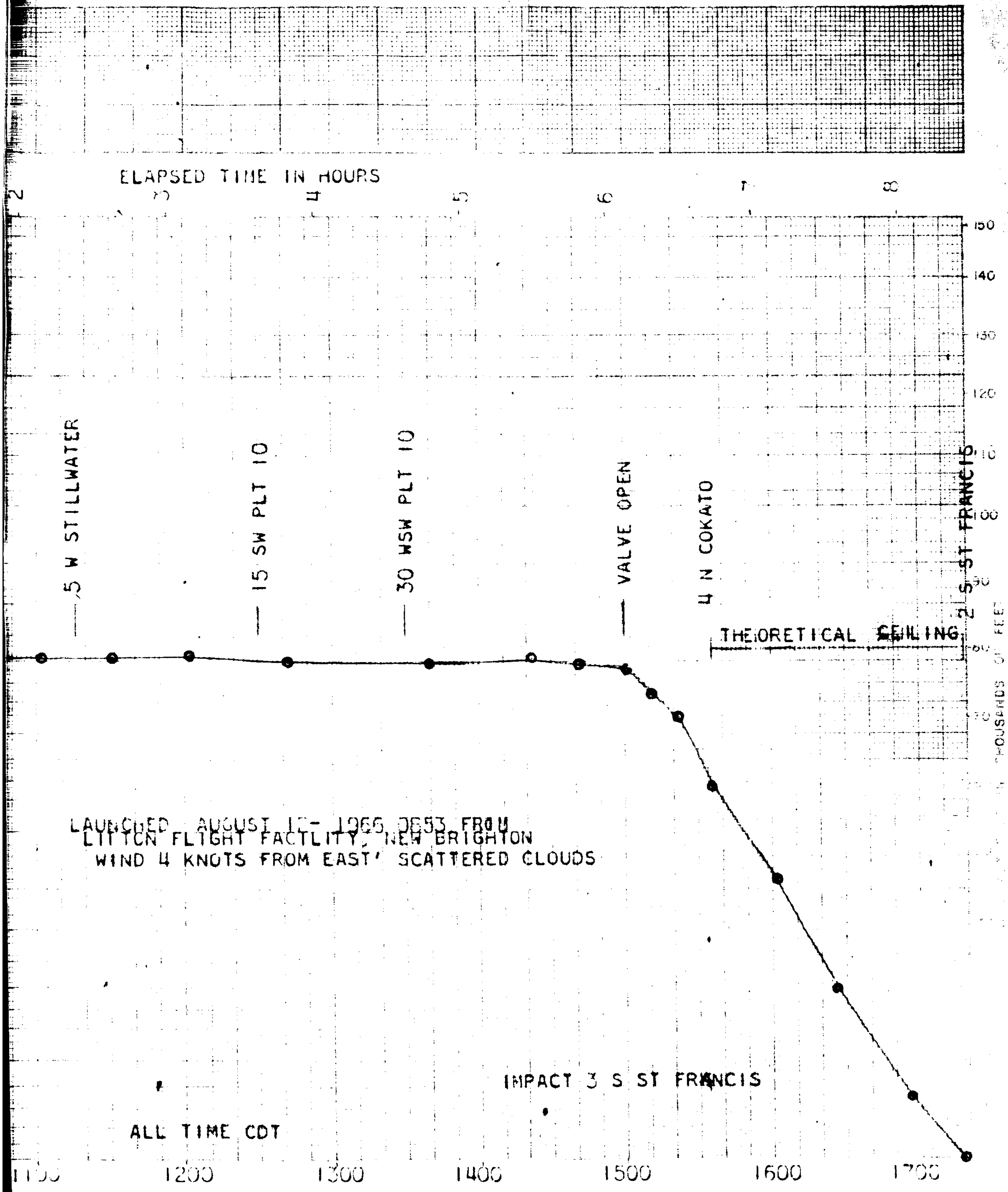
| BALLOON TYPE | NUMBER | MATERIAL | WEIGHT |
|---|---|---|---|
| 77-1-1 | 3DRS803 | 1.5 MIL | 199LBS. |

ALTITUDE DATA




TEMPERATURE DATA





ELAPSED TIME IN HOURS
2
6
8
150
140
130
120
110
100
THOUSANDS OF FEET
5 W STILLWATER
15 SW PLT 10
30 WSW PLT 10
VALVE OPEN
4 N COKATO
2 S ST FRANCIS
THEORETICAL CEILING
LAUNCHED AUGUST
LITTON FLIGHT FACILITY, NEW BRIGHTON
WIND 4 KNOTS FROM EAST' SCATTERED CLOUDS
IMPACT 3 S ST FRANCIS
ALL TIME CDT
1100
1200
1300
1400
1500
1600
1700

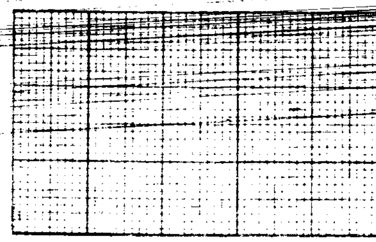
FLIGHT NO. 3037 DATE AUGUST 26 1966

FOR 59015

LOAD ON BALLOON 290

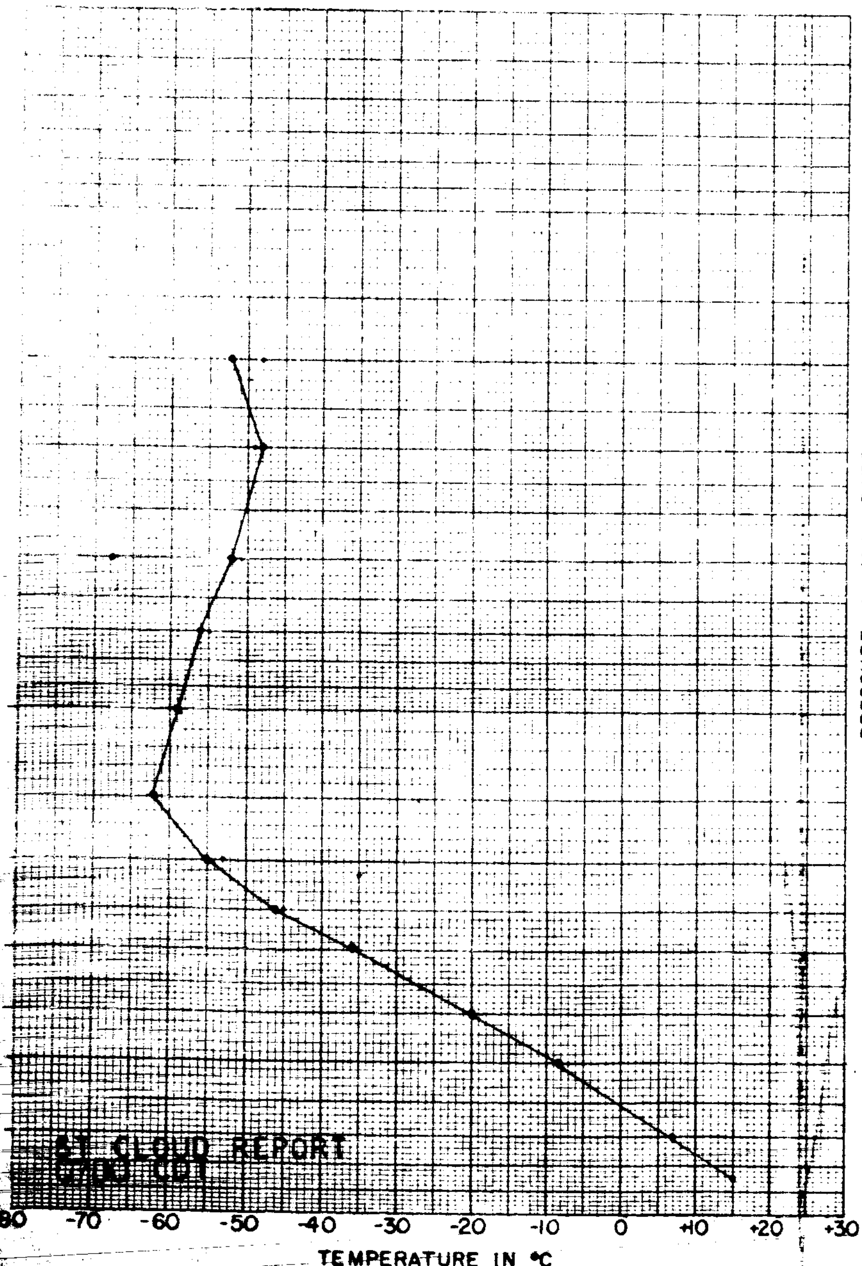
FREE LIFT 94 LBS= 9%

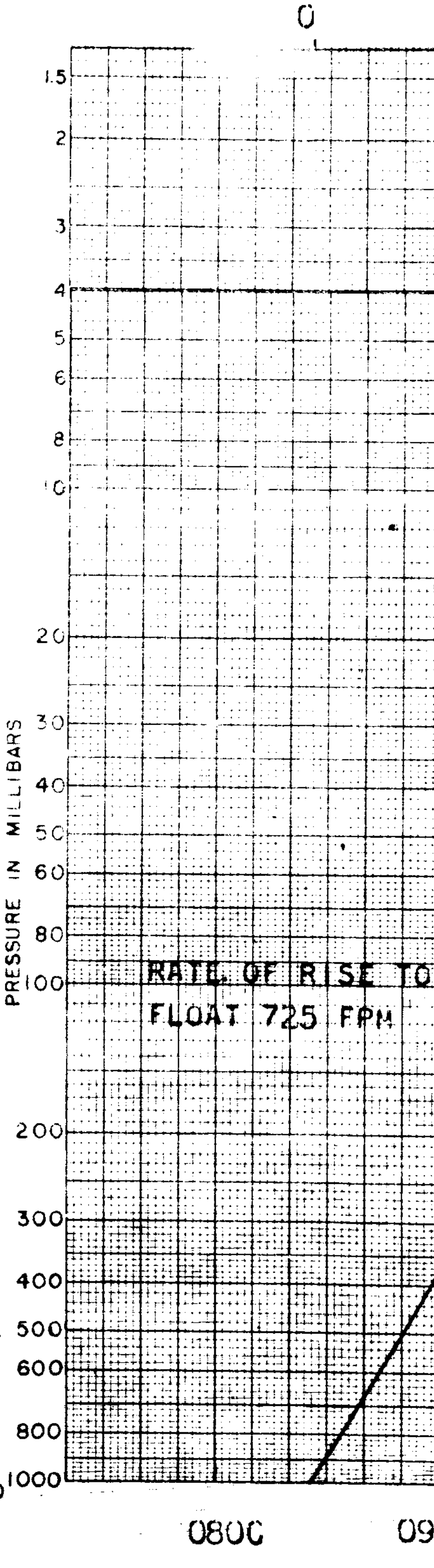
| BALLOON TYPE | NUMBER | MATERIAL | WEIGHT |
|---|---|---|---|
| SF 197.76-100 | NS 264 | 1.0 MIL | 755 LBS. |



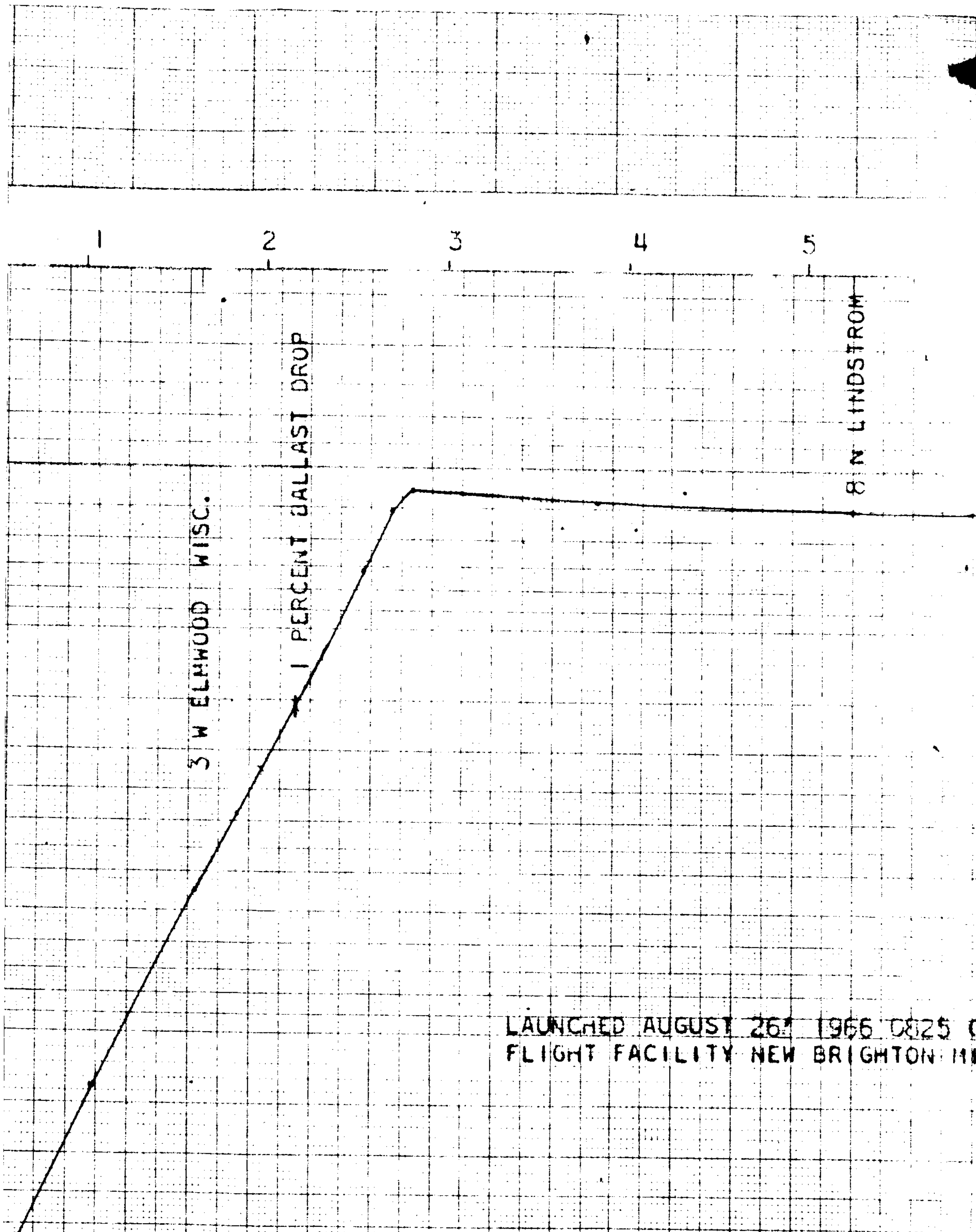
ALTITUDE DATA

TEMPERATURE DATA



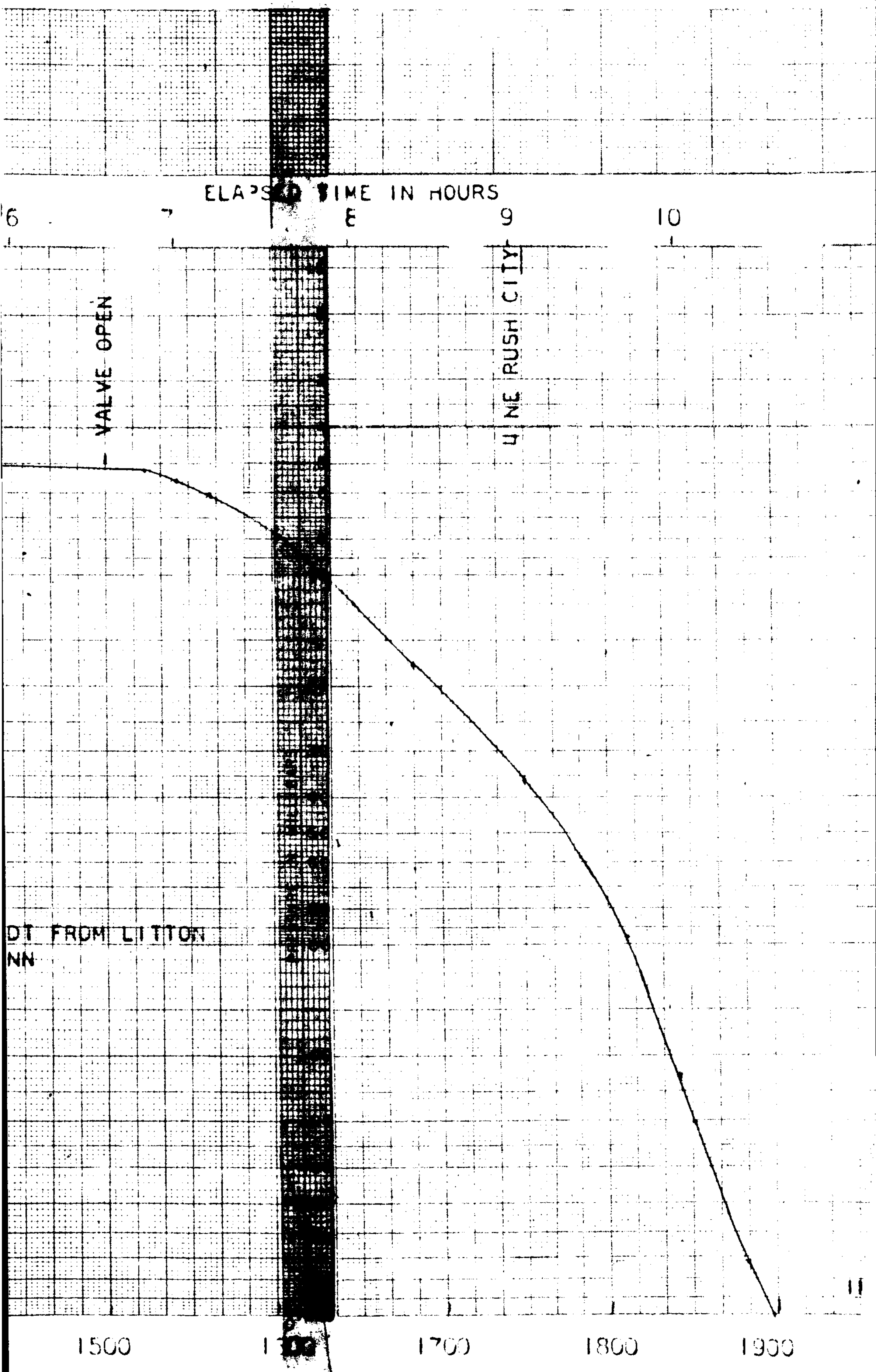




43-1



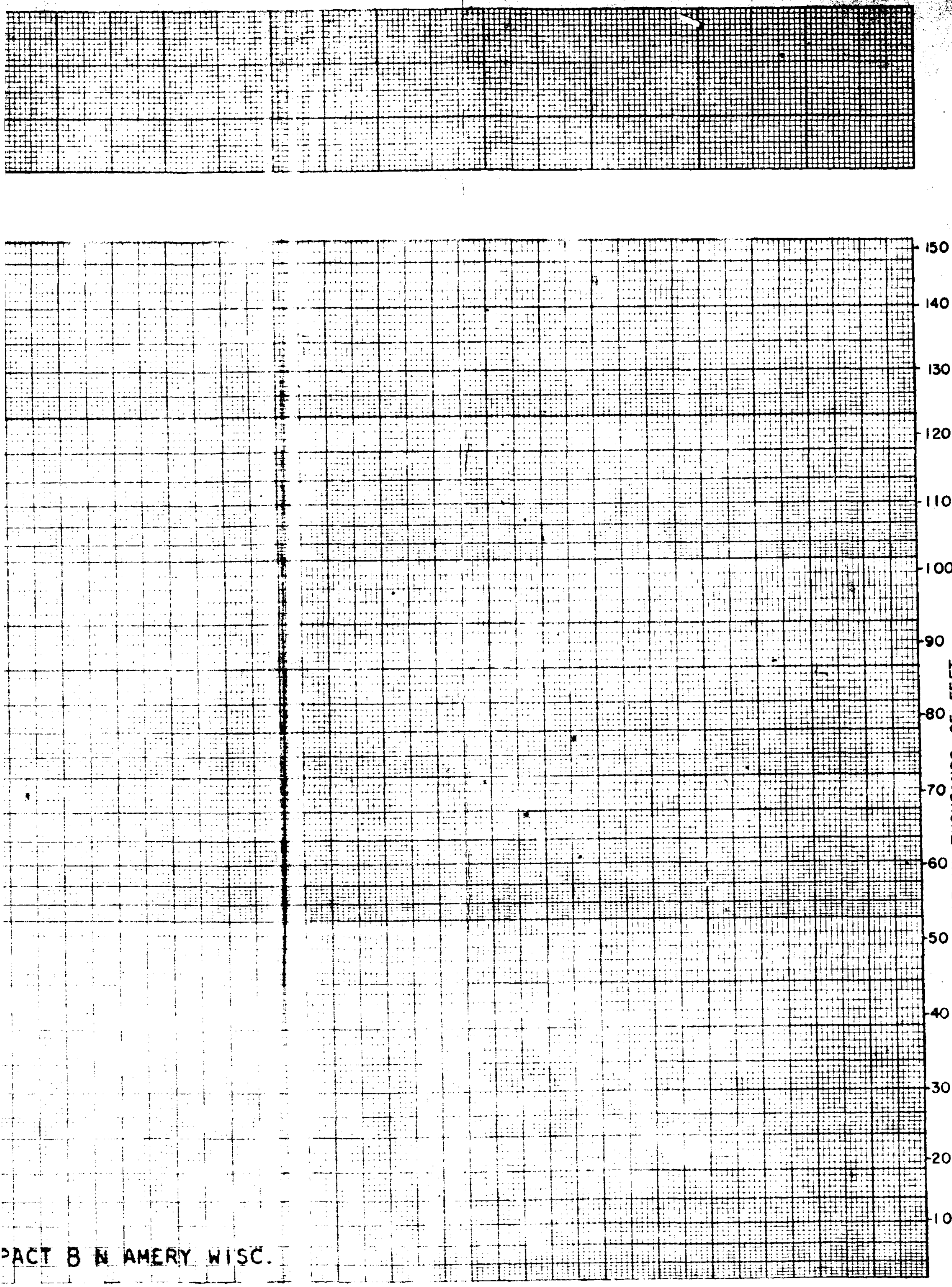

LITTON IND, AOPI

43-2


TIME IN HOURS
6
7
8
9
10
VALVE OPEN
NE RUSH CITY
DT FROM LITTON
NN
1500
1700
1800
1900



43-3


150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
NACA ALTITUDE IN THOUSANDS OF FEET
PACT B N AMERY WISC.

43-4